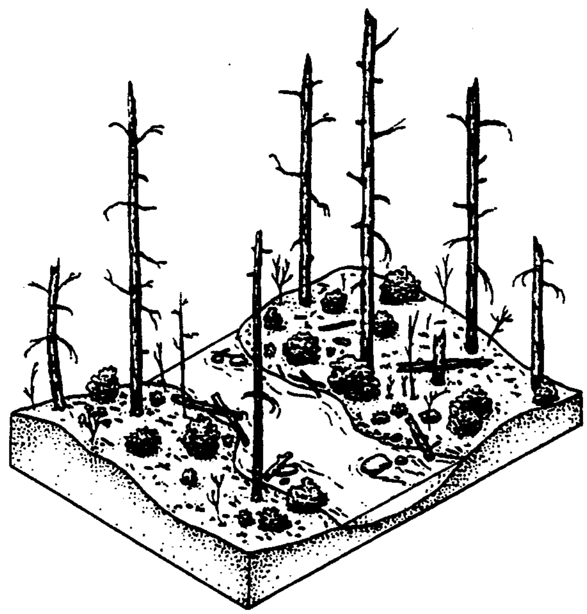
EFFECTS OF FIRE ON WILDERNESS STREAM ECOSYTEMS

IN THE FRANK CHURCH - RIVER OF NO RETURN WILDERNESS

REPORT OF 1991 STUDIES



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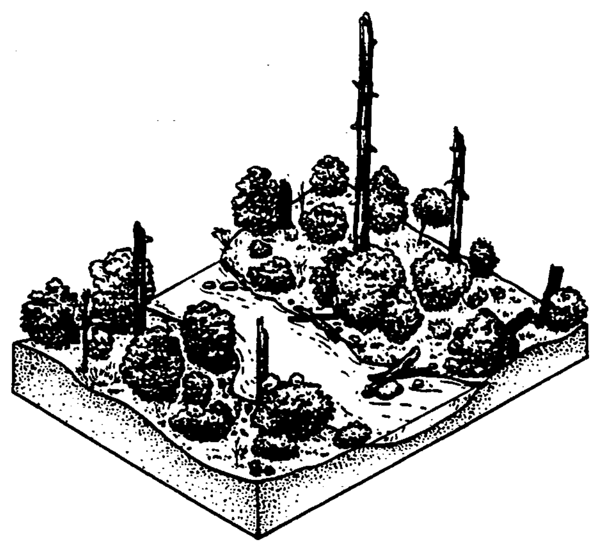

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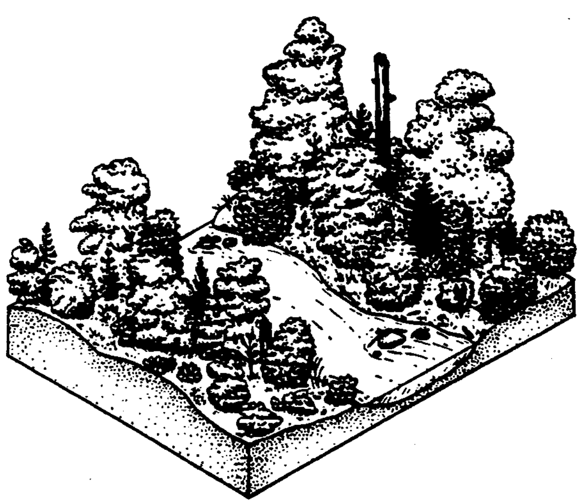

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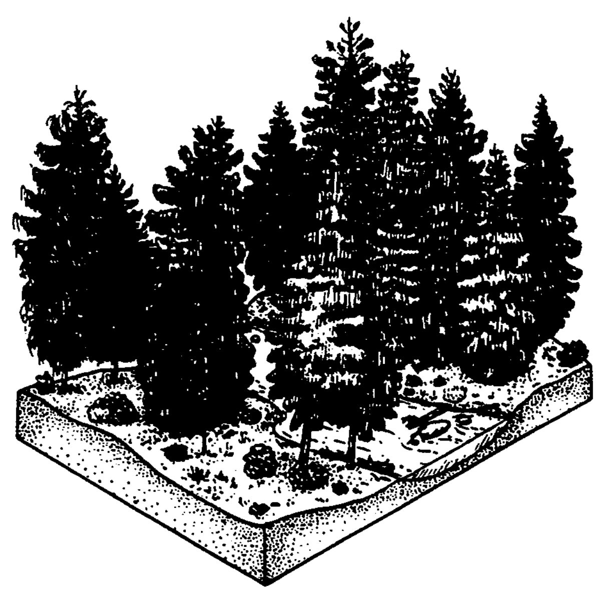

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FINAL REPORT TO THE PAYETTE NATIONAL FOREST

EFFECTS OF FIRE ON WILDERNESS STREAM ECOSYSTEMS IN THE FRANK CHURCH - RIVER OF NO RETURN WILDERNESS

REPORT OF 1991 STUDIES

by

G. W. Minshall, P. D. Dey, P. Koetsier, C. T. Robinson

Stream Ecology Center
Department of Biological Sciences
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Pocatello, Idaho 83209

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF FIGURES (cont.)

LIST OF TABLES

INTRODUCTION

The overall purpose of this study was to examine the effects of wildfire on stream communities and their habitats in the Frank Church River of No Return Wilderness for resource management applications. The study involved streams in the Big Creek and Chamberlain Basins, and is presented in five segments of interest. The first segment examined temporal trends in the macroinvertebrate assemblage in Cliff Creek over four years (1988-1991). The second segment analyzed temporal trends in macroinvertebrate assemblages for four streams sampled in 1990 and 1991 (Cliff, Cougar, Dunce, and Goat Creeks) and impacted by the Golden Fire. Here, a primary objective was to confirm the observed variation among streams (Robinson and Minshall 1991), and to determine possible reasons for them through a reconnaisance of upper Cliff and Goat Creeks. This segment also allowed for a third year "marker" in the recovery sequence among streams. The third segment compared the effects of the Golden Fire from samples collected in 1991 to those of the Sliver Creek Fire, also sampled in 1991, on macroinvertebrate assemblages from respective streams in the Big Creek catchment. This segment permited a comparison of the Golden Fire and Sliver Creek Fire streams at an equivelant point in time. The fourth segment examined differences in burn and reference streams in the Chamberlain Basin catchment that were impacted by the Sliver Creek Fire. Specific objectives for this segment was to document fire effects over a wider range of stream sizes and watershed burn intensities, and also increase the number of replicates (for increased statistical power and better definition of mean response) for streams of each size and type. The final segment was a first attempt to observe the immediate effects of wildfire on aquatic communities. Here, samples of macroinvertebrate drift and water chemistry were collected during a rather low intensity wildfire in September 1991 on Dave Lewis Creek and compared with samples from Pioneer Creek, a reference stream.

METHODS

General methods used for the various segments of this study are summarized in Table 1. These are relatively routine in stream ecology and are described in detail in standard reference sources (Weber 1973, Greeson et al. 1977, Lind 1979, Merritt and Cummins 1984, APHA 1990) or in more specific references listed in Table 1. In particular, the ratio of bankfull depth to baseflow depth (H/L) and the difference between these values (H-L) are calculated as indices of channel activity. Since annual maximum stream temperatures consistently occur during the July sampling season, annual temperature range can be estimated from observed stream temperatures (minimum temperature = 0). Mean substratum size was determined by measuring 100 subtrata randomly sampled throughout the channel and along a significant reach of stream. Methods used for sampling macroinvertebrates are described in Platts et al. (1983). Procedures for sample analysis also are described in Table 1. Macroinvertebrates were examined in terms of density, biomass, species richness, Simpson's Index (C), Shannon's Diversity (H'), functional feeding groups, and specific taxon changes. More detailed methods are described below for specific study segments. Locations of study streams are summarized in Table 2.

Cliff Creek Temporal Study: 1988-1991

The objective of this segment was to examine temporal changes in the macroinvertebrate assemblage and associated physical and chemical habitat in Cliff Creek over four years beginning in pre-fire July 1988 and ending in July 1991. This segment examined the delayed spatial and temporal effects by wildfire on streams having catchments partially burned. Cliff Creek is ideal for this sort of analysis because the 1988 Golden Fire impacted only the catchment headwaters (Fig. 1). The study

Table 2. SUMMARY OF VARIABLES, SAMPLING METHODS, AND ANALYTICAL PROCEDURES FOR EVALUATING THE EFFECTS OF WILDFIRE ON STREAM ECOSYSTEMS

VARIABLE	SAMPLE TYPE	SAMPLING METHOD	ANALYTICAL METHOD	REFERENCE
A. Physical				
1. Temperature (°C)	P	Maximum-Minimum recording thermometers.	Direct Observation	
2. Discharge (m^3/s)	T	Velocity-depth profiles.	Calculation: Q=W D·V; where W=width, D=mean depth, and V=velocity.	Bovee and Milhous 1978
Width (0.1m)	P	Nylon-reinforced meter tape.	Determine width of water and bankful width.	Buchanan and Somers 1969
Depth (0.1m)	T	Meter stick.	Determine water and bankful depths at sufficient intervals to give a good estimate of the mean. No more than 10% of flow should pass between measurements.	
Velocity (0.1m/s)	T	Small Ott C-1 current meter.	Determine velocities at 0.6 x depth (from the surface) at sufficient intervals to give a good estimate of the mean. No more than 10% of the flow should pass between measurements. Estimate bankful velocities from Manning's equation.	Gregory and Wailing 1973
3. Channel Gradient (%)	P	Inclinometer.	Measure water surface elevations over extended (150m) lengths upstream and downstream of the discharge transect.	
4. Substrate Particle Size	R	Select 100 rocks at random, measure L, W, and D axes.	Calculate mean volume , median diameter, CV's, distributions	Leopold 1970
5. Embeddedness	R	Ocular, adjacent to previously mentioned 100 rocks.	Optical determination of degree of embeddeness by silt and sand	Platts et al. 1983
B. Chemical	P	"Grab" samples from center of stream.		
1. Alkalinity (mg/l)			Gran (in waters <40mg/l alkalinity) or methyl orange titration.	Talling 1973 APHA 1989
2. Hardness (mg/l)			EDTA titration.	APHA 1989
3. Specific Conductance (μmhos)		Determine in the field.	Temperature compensated portable YSI meter. Estimate total dissolved solids using standard conversion factor.	APHA 1989
C. Biological				
1. Periphyton	P/R	Collect samples from five separate cobblestones. Remove material from known area. Brush and rinse three times following prescribed technique. Collect material from each rock on a separate pre-combusted, tared, glass-fiber filter (Whatman GFF).	Acetone extraction of chlorophyll followed by spectro-photometric assay with correction for phaeopigments. Recombine acetone with sample and evaporate to dryness. Determine AFDM as described below.	Stockner and Armstrong 1971 Lorenzen 1966
2. Benthic invertebrates	P/R	Surber sampler fitted with 250 μm mesh net. Collect 5 samples per site in proportion to principal habitat types. Disturb substratum to depth of 10cm, remove all organic matter from larger inorganic particles, preserve in 5% formalin.	Separate invertebrates by species, count, dry at 60°C, and weigh. Determine population densities and biomass, species richness, dominance, diversity, and functional feeding group composition.	Platts et al. 1983 Merritt and Cummins 1984
3. Benthic organic matter	P/R	Recover from Surber samples described above.	Estimate percent composition of various plant components (including charcoal) dry at 60°C, ash at 550°C, determine total AFDM.	

P = point sample
R = random throughout a defined lineal reach
T = transect across stream

Table 2. Stream research sites for Big Creek wildfire study.

Stream	Basin	Type	Order	Link	Elevation	Coordinates
Cliff Creek	Big Creek	Burn	2	10	1145	114’51";45’7"
Cougar Creek	Big Creek	Burn	3	14	1095	114’49";45’7"
Goat Creek	Big Creek	Burn	2	6	1125	114’48";45’7"
Dunce Creek	Big Creek	Burn	2	6	1065	114’47";45’7"
Mouth Cave Creek	Big Creek	Reference	3	41	1220	114’57";45’8"
West Fork Cave Creek	Big Creek	Reference	3	9	1365	114’58";45’11"
Upper Pioneer Creek	Big Creek	Reference	2	9	1485	114’51";45’5"
Pioneer Creek	Big Creek	Reference	3	18	1165	114’51";45’6"
Crooked Creek	Big Creek	Burn	3	17	1780	115’02";45’18"
Packhorse Creek	Big Creek	Burn	2	5	1780	115’02";45’12"
Sliver Creek	Big Creek	Burn	2	4	1880	115’04";45’13"
East Fork Whimstick Creek	Chamberlain	Burn	2	6	1745	115’01";45’18"
South Fork Whimstick Creek	Chamberlain	Burn	3	11	1730	115’01";45’17"
Main Whimstick Creek	Chamberlain	Burn	4	26	1710	115’01";45’17"
East Fork McCalla Creek	Chamberlain	Reference	2	6	1915	115’08";45’17"
3rd Order McCalla Creek	Chamberlain	Reference	3	12	1890	115’08";45’17"
4th Order McCalla Creek	Chamberlain	Reference	4	38	1820	115’06";45’18"

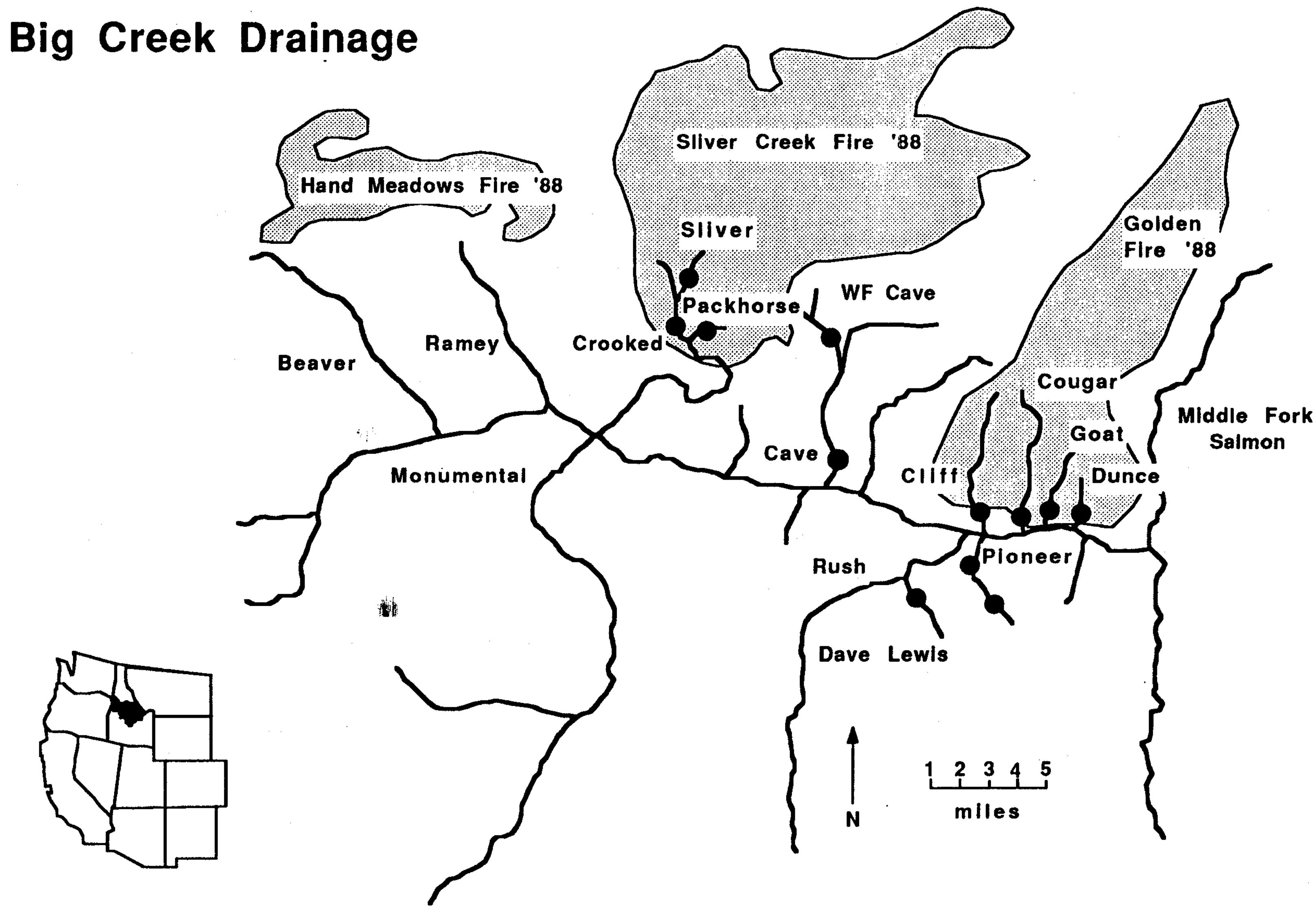


Figure 1. Site locations for the Big Creek Study 1991.

site was located downstream from the fire perimeter, about 200 m upstream of the Cliff Creek confluence with Big Creek.

Big Creek Burn and Reference Stream Study: 1990-1991

Objectives of this segment were to determine possible reasons for apparent discrepancies (variation) in response among streams noted in the 1990 results, and examine temporal changes in these four streams impacted by the 1988 Golden Fire. The streams were sampled in July 1990 and July 1991 and included Cliff, Cougar, Goat, and Dunce Creeks (Fig. 1). These sites comprised a range of stream sizes to provide a spatial scale of resolution to the study of fire impacts on streams. Another objective compared burn streams to reference streams within the Big Creek catchment.

Golden Fire versus Sliver Creek Fire

This segment of the study had three objectives, with an overall goal to obtain a more complete measure of the variability within and among streams of different sizes as a result of fire. One objective was to compare sites impacted by the Golden Fire to those impacted by the Sliver Creek Fire. This aspect of the study included sites from Chamberlain Basin (Whimstick and McCalla Creeks) and Big Creek Basin (Cliff, Cougar, Dunce, Goat, Pioneer, and Cave). In addition, the Sliver Creek Fire impacted streams from both basins, thus a second objective was to compare streams between basins but impacted by the same fire. This aspect of the study included samples collected in July 1991 from Sliver Creek, Packhorse Creek and Crooked Creek of the Big Creek catchment and Whimstick and McCalla Creeks from Chamberlain Basin. The third aspect compared Golden Fire streams with Sliver Creek Fire streams within the Big Creek catchment.

Chamberlain Basin: Burn versus Reference Streams

Two catchments within Chamberlain Basin were sampled in July 1991 to examine the effects of the 1988 Sliver Creek Fire on stream macroinvertebrate assemblages. Whimstick Creek catchment was impacted by fire and McCalla Creek catchment served as a reference (unburned) catchment. Three streams (2nd-4th order) were sampled from each catchment for comparison (Table 1). Both catchments are higher elevation and lower gradient systems than streams found in Big Creek catchment or in the 1979 Mortar Creek Fire area thus adding a broader range of stream types to our analyses of fire effects on streams.

Dave Lewis Study: September 1991

The Dave Lewis Fire presented the opportunity to examine the immediate effects of wildfire on streams. Macroinvertebrate drift samples were collected during this low intensity fire from Dave Lewis Creek and Pioneer Creek (reference site). Drift samples were standardized to number of taxa/m^3 of filtered water for analyses. Further, water chemistry, including nitrogen and phosporus concentrations, also was determined from both streams. In addition to standard Two-sample t-tests, multiple regression analysis assessed the predictability of physiochemical factors on macroinvertebrate taxa in burned and reference streams. Seven of 18 drift taxa were omitted from the regression because of low frequencies of occurrence.

RESULTS

Cliff Creek Temporal Study: 1988-1991

<u>Chemical and Physical Measurements:</u> Discharge was higher in

post-fire samples (1990, 1991) than in pre-fire samples (1988) with the highest value of 0.32 m^3/s occurring in 1990 (Table 3). Substrate length also peaked in 1990 with a mean of 25.3 cm (Table 3). The apparent doubling of alkalinity in 1991 is highly suspect because neither total hardness or specific conductance showed comparable increases (Table 3).

Periphytic and Benthic Organic Matter: Chlorophyll a levels increased in 1991 over both 1988 levels and 1990 levels (Fig. 2). Periphyton was not sampled in 1989. However, the ash-free-dry-mass (AFDM) of periphyton was similar in 1991 to 1988 levels, following an apparent decrease in 1990. The ratio of AFDM to chlorophyll a (B/C ratio) decreased steadily from a value near 8 in 1988 to a value of 2 in 1991.

Benthic organic matter (BOM) was about 50% lower in the three years following the fire than in 1988 suggesting that the higher flows experienced may have flushed BOM from the study area (Fig. 3). The lowest quantity of BOM occurred in 1991. In contrast, percent charcoal of BOM increased over time and reached 21% in 1991, suggesting that these downstream areas may experience delayed effects from upstream burn areas.

Macroinvertebrate Community Analysis: Mean macroinvertebrate abundance decreased by half in 1989, increased in 1990, then decreased again in 1991, although the differences among years were not significant (Fig. 4). Macroinvertebrate biomass did not correspond with observed changes in abundance; biomass decreased from 1988 through 1990 then increased slightly from 1990 to 1991, although not reaching 1988 levels. Macroinvertebrate functional feeding group abundance and biomass in Cliff Creek remained relatively constant during the study period (Table 4).

Species richness remained relatively constant from 1988 to 1990. Mean species richness decreased to 20 species in 1991, five less than in pre-fire 1988 (Fig. 4). Shannon-Weiner diversity (H') displayed a similar pattern as species richness.

Table 3. Physical and chemical data for Cliff Creek in 1988, 1990, and 1991.

Parameter	1988		1990		1991	
	Mean	CV	Mean	CV	Mean	Cv
SLOPE (%)	13		10		11	
ELEVATION (m)	1145		1145		1145	
DISCHARGE (m^3/s)	0.04		0.32		0.18	
ANNUAL TEMP RANGE	10		13		13	
WIDTH, HIGHFLOW (m)	4.80		3.54		3.83	
DEPTH, HIGHFLOW (m)	0.72	0.47	0.47	0.26	0.49	0.19
DEPTH, BASEFLOW (m)	0.08	0.88	0.19	0.22	0.17	0.37
DEPTH, (H-L)	0.64		0.28		0.32	
DEPTH(H/L)	9		2.5		2.9	
(HW/HD)/(HW/LD)	0.11		0.40		0.34	
SUBSTRATE LENGTH (cm)	16.2	0.63	25.3	0.74	22.54	0.85
ALKALINITY (mg/l CaCO3)	35		35		77	
HARDNESS (mg/l CaCO3)	66		66		71	
pH	8.2		8.2		8.2	
SPECIFIC CONDUCTANCE (umhos/cm @25 C)	61		61		73	
CHLOROPHYLL (ug/cm2)	0.24	0.88	0.20	1.35	0.88	0.14
CHL. AFDM (g/m2)	1.93	1.04	0.9	0.51	1.8	0.64
B/C (AFDM/CHLOROPHYLL)	8.04		4.48		2.05	
BOM (g/m2)	98.4	1.24	41.5	0.87	25.6	0.41

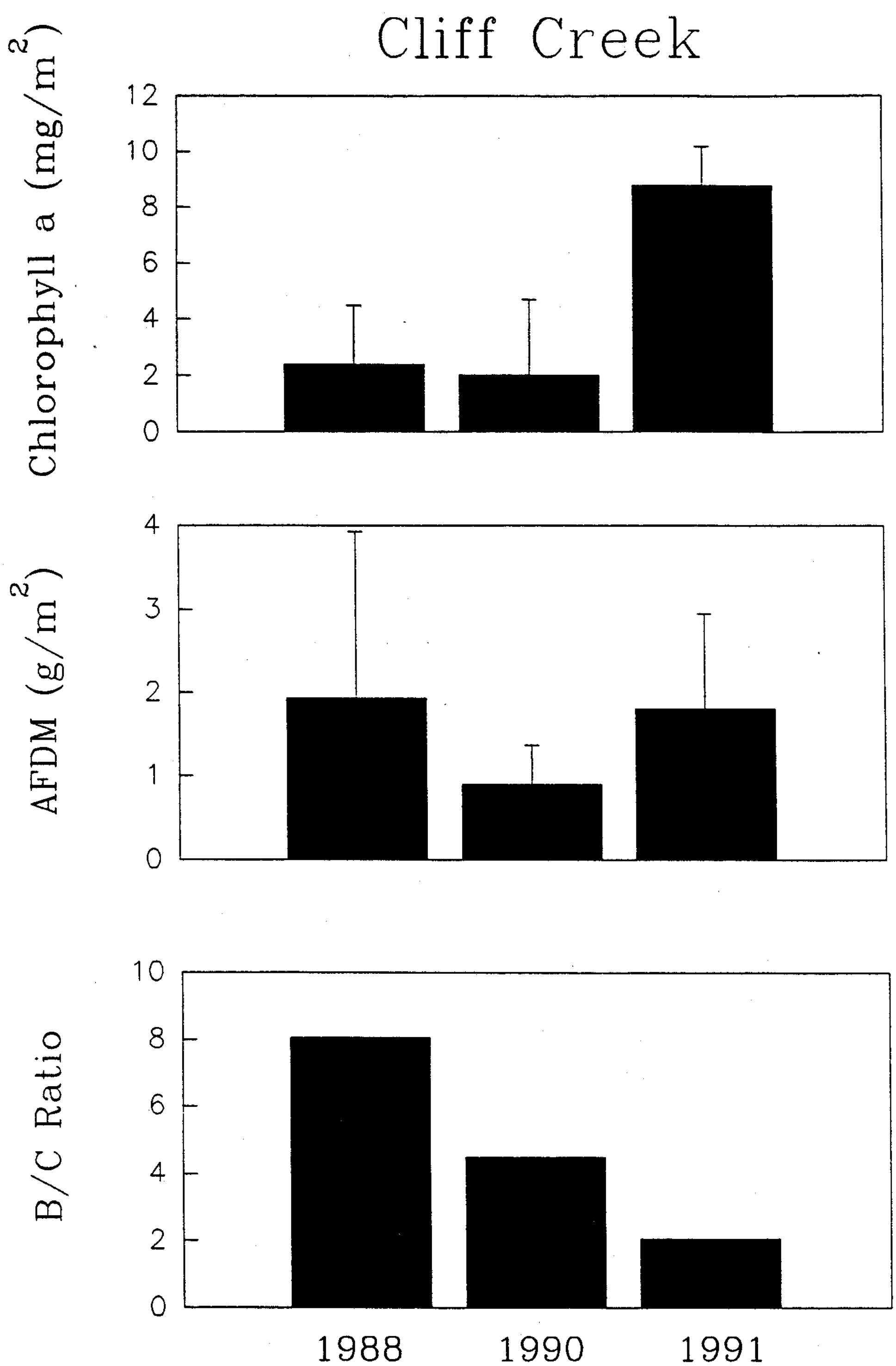


Fig. 2. Periphyton chlorophyll a (mg/m^2), chlorophyll Ash–Free–Dry–Mass (g/m^2), and Biomass/Chlorophyll (B/C) ratio for Cliff Creek in 1988, 1990, and 1991. Vertical bars represent one standard deviation from the mean (n=5).

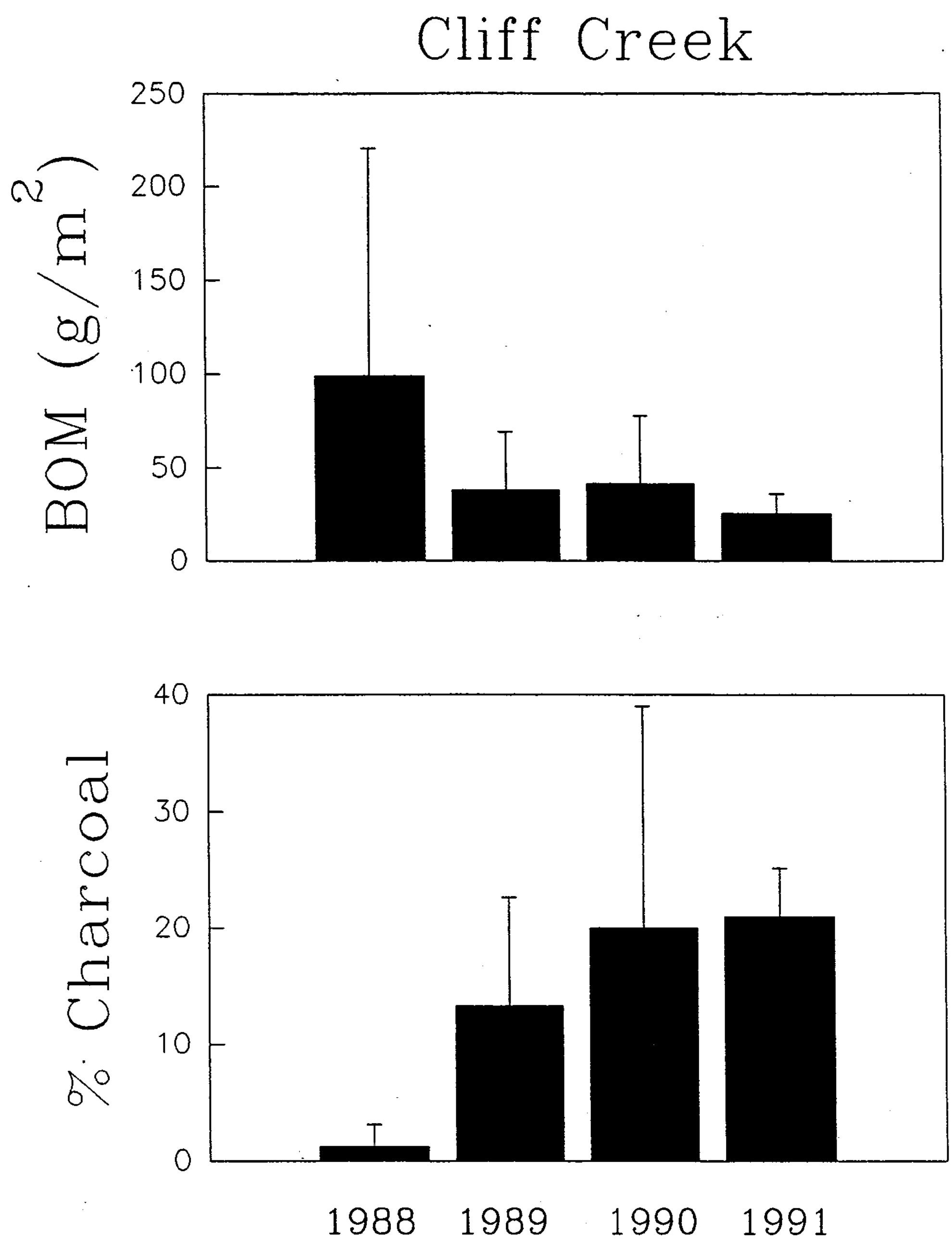


Fig. 3. Benthic organic matter (g/m2) and percent charcoal of BOM for Cliff Creek in 1988, 1989, 1990, and 1991. Vertical bars represent one standard deviation from the mean (n=5).

Cliff Creek

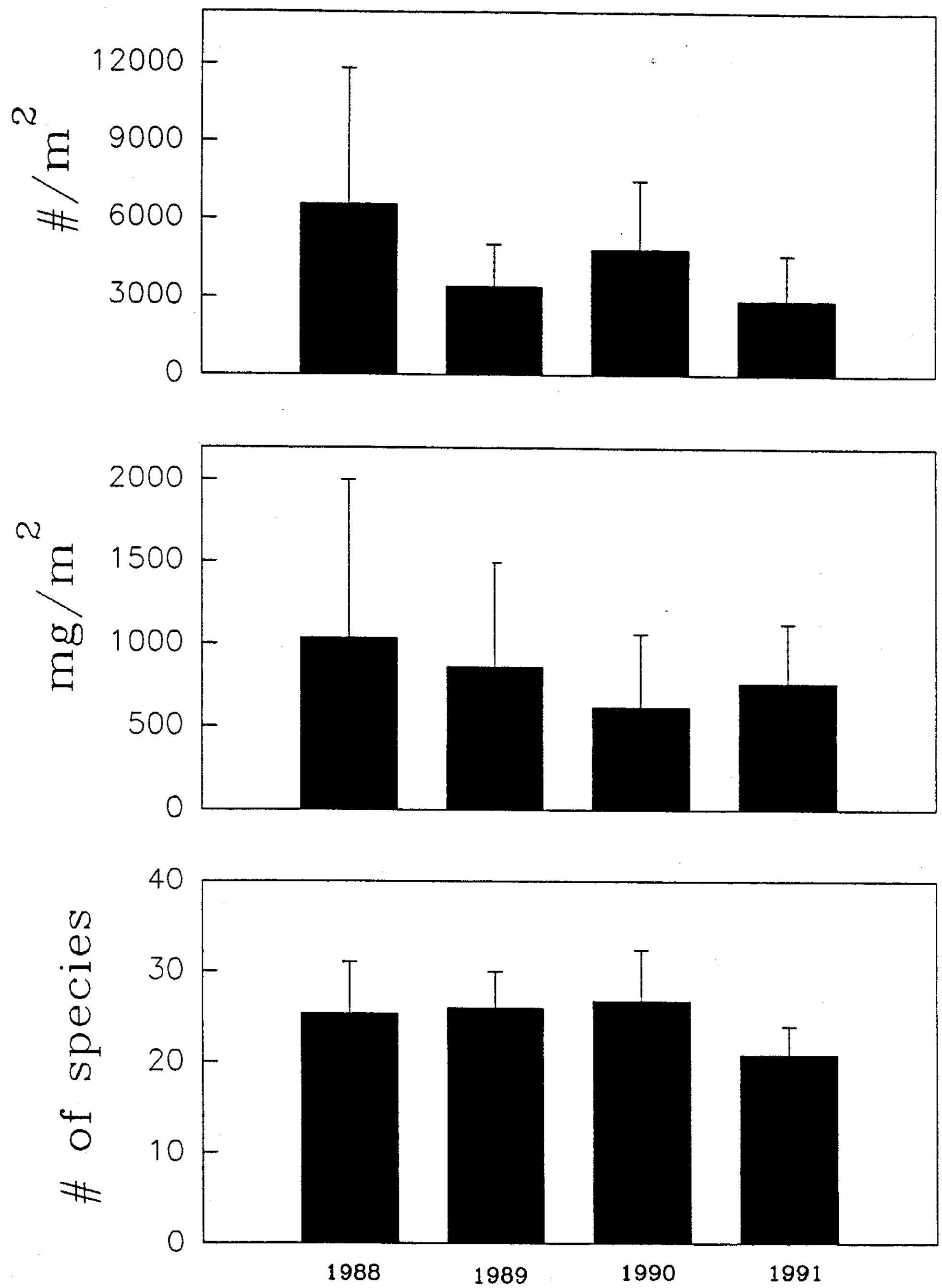


Fig. 4. Mean abundance, biomass, and species richness of macroinvertebrates collected at Cliff Creek in 1988 through 1991. Vertical bars represent one standard deviation from the mean (n=5).

Table 4. Mean and relative abundances (#/m2) and biomass (mg/m2) of macroinvertebrate functional feeding groups (FFG) collected at Cliff Creek in 1988 through 1991.

FFG	1988		1989		1990		1991	
	mean	rel %	mean	rel %	mean	rel %	mean	rel %
ABUNDANCE								
Predator	537.8	8.2	435.3	12.9	667.9	14.1	224.1	12.7
Gatherer	1150.2	17.6	512.2	15.1	761.8	14.5	275.3	15.8
Scraper	1267.6	19.4	1228.1	36.3	1195.1	29.1	384.1	21.7
Shredder	503.6	7.7	161.1	4.8	138.7	2.4	46.9	2.7
Filterer	559.1	8.6	303.0	9.0	337.2	8.3	100.3	5.7
Miner	2497.7	38.2	745.8	22.0	1720.0	30.5	736.2	41.7
BIOMASS								
Predator	63.1	6.1	4.5	10.6	88.7	15.1	83.2	12.7
Gatherer	190.0	18.4	3.7	8.7	162.8	24.2	102.4	15.6
Scraper	230.5	22.3	5.4	12.7	182.5	28.3	142.9	21.8
Shredder	205.6	19.9	9.6	22.6	10.4	1.9	17.1	2.6
Filterer	18.9	1.8	17.3	40.8	111.9	14.8	37.3	5.7
Miner	126.9	12.3	1.9	4.5	58.3	8.8	273.2	41.6

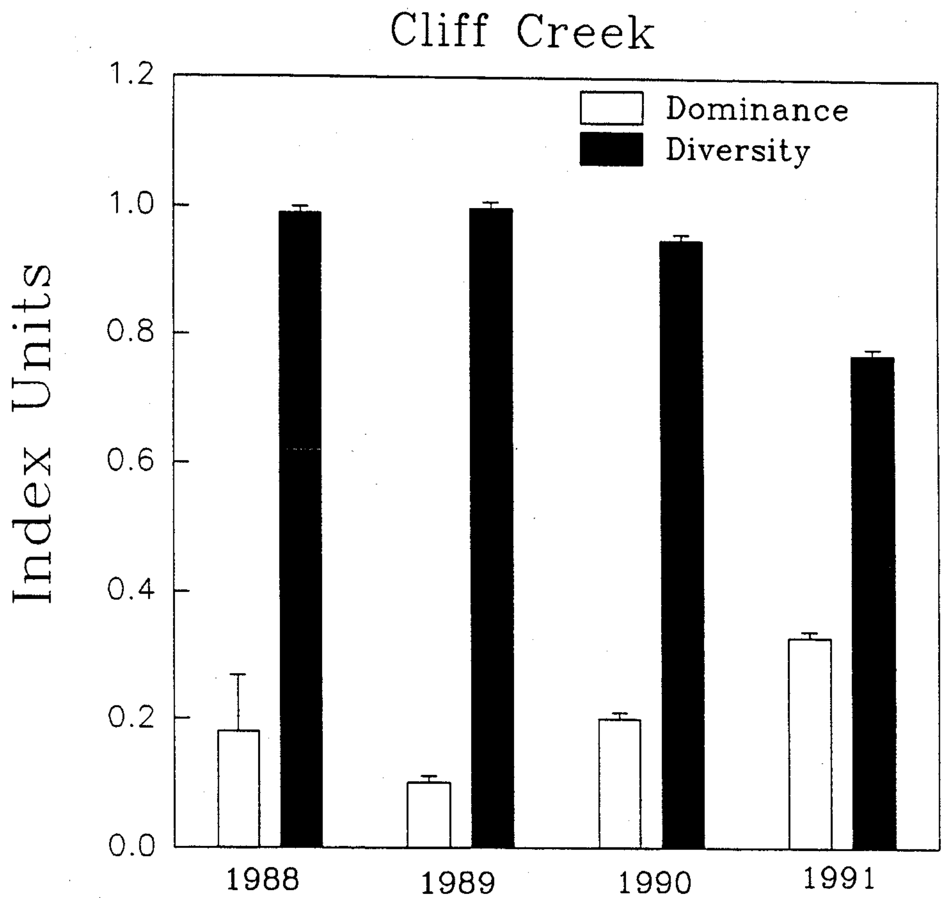


Fig. 5. Mean values for Simpson's Dominance (clear bars) and Shannon–Weiner Diversity (solid bars) for macroinvertebrate taxa collected at Cliff Creek in 1988 through 1991. Vertical bars represent one standard deviation from the mean (n=5).

Diversity was greatest in 1988, decreased slightly in 1990 and decreased again in 1991. Simpson's dominance index (C) displayed a pattern opposite that of H'. Dominance decreased in 1989, then increased in 1990 and 1991 (Fig. 5). The pattern of change in diversity and dominance suggested that abundance of some species was increasing, perhaps due to more efficient resource utilization or through competition.

Macroinvertebrate Taxa Analysis: The ten most abundant taxa comprised over 80% of the assemblage in July 1988 through 1991 (Table 5). Six of these ten taxa were found on all sample dates and included *Baetis bicaudatus*, *Cinygmula*, *Heterlimnius*, *Suwallia*, Chironomidae, and Oligochaeta and are favored by disturbance. *B. bicaudatus, Heterlimnius* and Chironomidae steadily increased in absolute and relative abundance in 1988 through 1990 then decreased in 1991. Oligochaeta decreased in 1989 then increased in 1990 and 1991, although abundance in 1991 was less than 1988 levels. *Cinygmula* absolute and relative abundances decreased throughout the four years. *Suwallia* relative abundance increased in 1989, then decreased in 1990 and 1991. In contrast, its mean absolute abundance decreased in 1989, increased in 1990, then decreased in 1991. A total of 101 taxa were identified from Cliff Creek, with their abundances and biomasses listed in Table 6.

Big Creek Burn Stream Study: 1990-1991

Chemical and Physical Measurements: Discharge decreased in Cliff Creek from .32 m^3/s in 1990 to 0.18 m^3/s in 1991, although still remaining higher than prefire discharge. Discharge was similar between years in Cougar Creek and increased in Dunce and Goat Creeks from 1990 to 1991 (Table 7). Mean baseflow depth was similar between years for all sites. Changes in mean substrate size varied across streams with the greatest change occurring in

Table 5. Densities (#/m2) and relative percentages of the ten most abundant invertebrate taxa collected at Cliff Creek in 1988, 1989, 1990, and 1991.

TAXA	JULY 1988			JULY 1989			JULY 1990			JULY 1991		
	MEAN	STD	REL %	MEAN	STD	REL %	MEAN	STD	REL %	MEAN	STD	REL %
Baetis bicaudatus	312.6	457.4	4.8	334.8	269.3	9.9	723.4	721.0	14.9	224.1	148.5	7.9
Baetis intermedius							140.8	309.0	2.9			
Chironomidae larvae	353.2	476.6	5.4	448.1	385.1	13.2	864.3	1274.7	17.8	138.0	52.5	4.8
Chironomidae pupae							136.6	108.7	2.8			
Cinygmula spp.	617.8	334.9	9.4	229.4	104.5	6.8	202.7	249.3	4.2	85.4	78.0	3.0
Drunella doddsi										32.0	17.5	1.2
Ephemerella infrequens				144.0	109.9	4.3						
Glossosoma spp.				328.1	291.9	9.7						
Heterlimnius spp.	387.3	410.7	5.9	409.5	282.0	12.1	672.2	369.7	13.8	224.1	160.4	7.7
Nematoda	275.3	833.2	4.2									
Oligochaeta	2116.9	2619.3	32.1	290.8	292.0	8.6	706.4	796.3	14.5	1707.2	1327.0	59.4
Ostracoda	273.2	863.8	4.2	189.4	102.5	5.6	151.5	46.1	3.1			
Polycentropus spp.	434.3	1347.1	6.6									
Serratella tibialis										32.0	40.9	1.0
Simulium spp.	284.9	77.2	4.4				155.8	194.7	3.2	85.4	45.7	3.1
Suwallia spp.	345.7	351.5	5.3	264.1	157.8	7.8	326.5	350.1	6.7	96.0	79.2	3.4
Zapada columbiana				132	179.7	3.9				32.0	15.1	0.9

Table 6. Absolute abundance and biomass of individual taxa for Cliff Creek in July of 1988 through 1991.

FFG/Taxa	ABUNDANCE (#/m2)								BIOMASS (mg/m2)							
	1988		1989		1990		1991		1988		1989		1990		1991	
	mean	std	mean	std	mean	std	mean	std	mean	std	mean	std	mean	std	mean	std
PREDATORS																
Alloperla spp.							10.1	8.5							3.5	5.2
Ceratopogonidae	35.2	53.7	26.7	37.0	4.3	9.5	10.7	8.9	4.4	8.8	3.2	4.2	0.2	0.4	360.5	191.7
Chelifera sp.	2.1	4.5			38.4	35.9	1.1	5.9	0.1	0.2			3.1	3.6	0.1	0.1
Chloroperlidae					44.8	100.2							1.2	2.6		
Diapriidae			1.3	3.8							0.1	0.4				
Dicronota sp.	2.1	6.7	18.7	18.7			1.1	9.5	0.0	0.1	1.1	1.3			0.6	1.2
Doroneuria sp.			1.3	3.8							0.8	2.4				
Empididae	1.1	3.4							0.0	0.1						
Glutops sp.					6.4	9.5	0.2	5.9					12.0	16.5	2.9	3.9
Hexatoma spp.							9.6	5.3							7.9	17.6
Hydracarina	10.7	10.1	24.0	18.7	51.2	48.5	32.1	20.5	0.5	0.8	0.8	0.7	1.1	1.2	5.4	9.7
Hydracarina sp. 2					12.8	17.5							0.4	0.4		
Isoperla sp.			2.7	4.9							0.3	0.5				
Limnophila sp.			2.7	7.5							0.7	2.0				
Limoniinae					2.1	4.8	5.3	4.3					0.1	0.3	0.8	1.3
Limoniinae pupae					2.1	4.8							4.1	9.2		
Megarcys sp.	27.7	17.6	4.0	5.5			10.7	13.9	15.6	13.8	23.5	36.2			0.1	0.2
Nematoda	275.3	833.2	36.0	39.9	121.6	214.5			1.1	2.9	0.5	0.4	1.3	1.7		
Oreogeton sp.			1.3	3.8							0.1	0.2				
Perlodidae					34.1	33.2							8.3	7.9		
Plecoptera	25.6	81.0							0.3	0.8						
Rhyacophila sp.							2.1	5.9							2.7	1.8
angelita	69.4	112.4	25.3	31.7	2.1	4.8	10.7	13.9	3.0	4.8	2.9	3.8	0.2	0.4	25.2	23.5
bifila					6.4	9.5							39.1	56.0		
hyalinata							7.5	5.3							1.6	1.2
rotunda	48.0	82.5							2.6	4.6						
vaccua			1.3	3.8							0.6	1.7				
vagrita			16.0	19.8	17.1	20.8					0.7	1.1	0.5	0.5		
vespula			4.0	11.3	27.7	34.2					1.5	4.4	1.6	1.6		
Stenus sp.			1.3	3.8							0.7	1.8				
Suwallia sp.	345.7	351.5	264.1	157.8	326.5	350.1	96.0	79.3	50.7	50.6	48.9	30.4	17.9	18.7	1.8	2.9
Staphylinidae							5.3	4.3							7.0	15.8
Tipulidae					4.3	5.8							0.3	0.4		
Coleoptera larvae					2.1	4.8							0.2	0.4		
Diptera adult					2.1	4.8							0.3	0.7		
Turbellaria	40.5	65.2	5.3	11.4			10.7	9.6	14.4	23.1	2.8	5.8			23.6	23.1

Table 6. (con't).

FFG/Taxa	ABUNDANCE (#/m2)								BIOMASS (mg/m2)							
	1988		1989		1990		1991		1988		1989		1990		1991	
	mean	std	mean	std	mean	std	mean	std	mean	std	mean	std	mean	std	mean	std
GATHERERS																
Ameletus sp.																
velox	4.3	9.0							0.4	0.8						
Ampumixis sp.	5.3	10.4							19.2	44.5						
Antocha sp.	4.5	7.5	6.7	18.9					0.0	0.1	0.6	1.8				
Apatania sp.	36.3	34.2	4.0	7.9					0.8	1.8	0.9	2.3				
Capniidae	5.3	9.1			6.4	14.3			0.3	0.6			0.3	0.7		
Collembola			6.7	12.7	2.1	4.8	9.6	9.5			0.1	0.2	0.0	0.1	0.1	0.2
Ecclisiomyia sp.	1.1	3.4	1.3	3.8					0.0	0.1	1.1	3.2				
Ephemerella sp.	17.1	54.0	13.3	14.8					0.1	0.3	1.2	1.6				
Hemerodromia sp.			1.3	3.8	4.3	9.5					0.1	0.2	0.1	0.2		
Heterlimnius sp.	387.3	410.7	410.0	282.0	672.2	369.7	224.1	160.4	24.3	24.3	32.0	17.0	72.5	48.7	0.2	0.4
Heterlimnius adult	10.7	14.2							2.6	3.6						
Hydrophilidae							3.2	4.3							61.0	91.9
Moselyana sp.					12.8	28.6							0.1	0.2		
Paraleptophlebia sp.	141.9	219.5	8.0	11.0					3.2	4.8	0.7	1.3				
Pericoma sp.			4.0	7.9							0.3	0.8				
Polycentropus sp.	434.3	1347.1							22.6	70.2						
Rhyacophila acropedes	41.6	67.8	49.3	63.5	23.5	23.1	10.7	12.2	23.4	32.8	39.0	40.1	86.6	92.4	46.6	32.0
Serratella tibialis	42.7	70.6					32.0	40.9	14.5	24.6					1.6	1.7
Stratiomyidae			1.3	3.8							0.5	1.4				
Trichoptera																
adult									0.4	0.9						
pupae									14.9	33.0						
SCRAPERS																
Baetis bicaudatus	312.6	457.4	334.8	269.3	723.4	721.0	224.1	148.5	17.3	28.5	13.0	11.3	37.8	26.1	0.3	0.3
Baetis intermedius					140.8	309.0							20.6	45.6		
Cinygmula sp.	617.8	334.9	229.4	104.5	202.7	249.3	85.4	78.0	57.5	41.8	5.6	2.7	33.9	41.2	0.8	1.6
Drunella sp.																
colordensis	109.9	104.1					33.1	19.2	60.5	51.5					10.1	8.1
doddsi			52.0	53.9	2.1	4.8	32.0	17.5	1.6	1.3	9.5	11.3	16.0	35.7	1.1	0.1
flavilinea					51.2	41.6							22.1	23.7		
spinifera					2.1	4.8							6.8	15.2		
Epeorus																
deceptivus			89.4	182.3	2.1	4.8					30.1	67.4	10.4	23.2		
grandis					2.1	4.8							13.5	30.2		

Table 6 (con't)

	ABUNDANCE (#/m2)								BIOMASS (mg/m2)							
	1988		1989		1990		1991		1988		1989		1990		1991	
	mean	std	mean	std	mean	std	mean	std	mean	std	mean	std	mean	std	mean	std
SCRAPERS (con't)																
Epeorus																
longimanus	188.9	228.4			2.1	4.8	21.3	24.5	9.7	19.5			1.0	2.2	4.8	8.1
Gastropoda					2.1	4.8							0.1	0.2		
Glossosoma sp.	8.5	14.0	328.1	291.9	2.1	4.8	9.6	5.9	0.6	0.9	28.5	25.6	0.9	2.1	12.0	7.0
Glossosomatidae					2.1	4.8							1.8	4.0		
Heptageniidae					10.7	13.1							0.7	1.1		
Neophylax sp.	4.3	7.5	2.7	4.9	42.7	36.2	9.6	9.5	6.7	13.5	1.8	3.9	13.1	11.6	31.3	24.9
Ephemerella hystrix					6.4	14.3							3.8	8.5		
Rhithrogena sp.			48.0	50.7							23.3	20.7				
SHREDDERS																
Capnia sp.	19.2	57.1	5.3	9.9			10.7	13.9	1.0	3.1	0.4	0.8			2.4	3.4
Clostoeca sp.									0.4	1.3						
Ephemerella infrequens			144.0	109.9							18.9	44.2				
Lara sp.			1.3	3.8							0.3	0.9				
Micrasema sp.	12.8	28.8	2.7	7.5					0.5	1.1	0.5	1.4				
Tipula sp.	14.9	18.3	5.3	8.1					79.5	176.2	168.4	311.0				
Yoroperla brevis	1.1	3.4	14.7	22.0	21.3	18.5	10.7	7.5	0.1	0.3	8.0	17.3	5.7	5.7	12.4	25.9
Zapada sp.	108.8	223.0	132.0	179.7	117.4	170.4	32.1	14.9	4.8	12.1	14.3	21.8	4.7	7.1	0.1	0.1
FILTERERS																
Arctopsyche sp.	1.1	3.4							5.0	16.0						
Brachycentrus sp.					6.4	14.3	5.3	4.3					0.4	0.8	13.6	7.7
Dolophilodes			65.4	99.7							170.5	245.8				
Oligoplectrum					6.4	9.5							2.6	3.9		
Ostracoda	273.2	863.8	189.4	102.5	151.5	46.1	3.2	4.3	3.6	11.3	2.2	1.6	3.4	1.7	105.1	76.5
Parapsyche elsis			22.7	26.4	2.1	4.8	10.7	8.5			170.4	274.3	78.5	175.6	13.4	12.2
Simulium	284.9	771.6	20.0	27.6	155.8	194.7	85.4	44.8	4.0	6.6	2.0	3.3	17.4	20.3	2.1	2.5
Prosimulium			5.3	15.1							0.4	1.0				
MINERS																
Chironomidae	353.2	476.6	448.1	385.1	864.3	1274.7	138.7	52.3	6.4	7.0	148.9	392.6	20.5	22.8	1.6	2.1
pupae	7.5	13.4			136.6	108.7			0.2	0.3			4.4	3.3		
adult					12.8	13.9							0.5	0.7		
Lumbriculus sp.	18.1	25.7							44.3	95.5						
Oligochaeta	2116.9	2619.3	290.8	292.0	706.4	796.3	1707.2	1326.3	33.7	49.2	22.7	22.7	32.9	50.0	1.9	4.3
OTHERS																
Amphipoda					14.9	17.9							0.1	0.1		
Other terrestrials	13.9	19.5			17.1	16.2			2.2	5.2			8.4	16.4		

Table 7. Physical and chemical data for Cliff Creek, Cougar Creek, Dunce Creek, and Goat Creek in 1990 and 1991.

STREAM	CLIFF 1990		CLIFF 1991		COUGAR 1990		COUGAR 1991		DUNCE 1990		DUNCE 1991		GOAT 1990		GOAT 1991	
	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
SLOPE (%)	10		11		12		12		15		15		18		18	
DISCHARGE (m^3/s)	0.32		0.18		0.11		0.10		0.02		0.15		0.01		0.09	
WIDTH, HIGHFLOW (m)	3.54		3.83		2.70		3.08		1.11		1.07		0.91		0.88	
DEPTH, HIGHFLOW (m)	0.47	0.26	0.49	0.19	0.49	0.4	0.45	0.08	0.24	0.34	0.22	0.18	0.23	0.39	0.18	0.34
DEPTH, BASEFLOW (m)	0.19	0.22	0.17	0.37	0.18	0.02	0.19	0.33	0.06	0.25	0.07	0.16	0.06	0.17	0.06	0.31
SUBSTRATE LENGTH (cm)	25.3	0.74	22.5	0.85	21.6	0.62	22.6	1.15	21.3	1.45	13.9	1.57	9.7	1.72	10.9	1.46
ALKALINITY (mg/l CaCO3)	35		77		46		36		76		82		86		49	
HARDNESS (mg/l CaCO3)	66		71		71		32		100		78		110		51	
pH	8.2		8.2		8.5		7.4		8.3		8.5		8.1		8.4	
SPECIFIC CONDUCTANCE (umhos/cm @25 C)	61		73		70		93		129		168		139		153	
ANNUAL TEMP RANGE (C)	13		13		11		12		13		13		13		10	
CHLOROPHYLL (ug/cm2)	0.20	1.35	0.88	0.14	0.07	0.59	0.11	1.11	0.13	0.47	0.46	0.76	0.87	0.76	0.04	1.4
CHL. AFDM (g/m2)	0.90	0.51	1.81	0.64	0.72	0.59	0.84	0.26	2.22	0.45	2.66	0.50	4.04	0.42	0.73	0.45
BOM (g/m2)	41.5	0.87	25.6	0.41	57.1	1.15	25.9	0.8	45.6	0.75	113.8	0.49	178.9	0.82	197.1	0.35
DEPTH, (H-L)	0.28		0.32		0.32		0.26		0.19		0.15		0.17		0.12	
DEPTH(H/L)	2.53		2.92		2.82		2.37		4.36		2.98		4.11		3.06	
(HW/HD)/(HW/LD)	0.40		0.34		0.35		0.42		0.23		0.33		0.24		0.33	
B/C (AFDM/CHLOROPHYLL)	4.50		2.05		10.28		7.63		17.08		5.78		4.64		18.25	

Dunce Creek. Here, mean substrate length dropped from 21.3 cm in 1990 to 13.9 cm in 1991 suggesting greater input of fine sediments. Mean substrate size was smaller and coefficients of variation (CV) greater in the smaller Goat and Dunce Creeks (Table 7). All sites had similar annual temperature ranges between years except for Goat Creek where the range decreased from 13°C in 1990 to 10°C in 1991.

Alkalinity at all streams either remained constant or decreased between years, except for the suspect 1991 increase in alkalinity in Cliff Creek (Table 7). This same pattern occurred with total hardness within streams and between years, except the increase in Cliff Creek was less dramatic and the decrease in other sites was more dramatic. Specific conductance was higher at all sites in 1991 than in 1990. No major changes occurred in pH levels between years within the study streams, although pH decreased from 8.5 in 1990 to 7.4 in 1991 in Cougar Creek. This pH decrease in Cougar Creek may simply be an artifact of sampling time.

Periphytic and Benthic Organic Matter: Interpretations of the chlorophyll a data were made difficult because of high sample variation. Chlorophyll a levels in Cliff Creek and Dunce Creek were higher in 1991 than 1990 (Fig. 6). Periphton AFDM also increased in 1991 from 1990 values in Cliff Creek. Chlorophyll a and AFDM values were similar between years for Cougar Creek. These patterns were reversed in Goat Creek where chlorophyll a and periphyton AFDM decreased from 1990 levels in 1991 suggesting differential recovery of riparian vegetation among sites.

The quantity of benthic organic matter (BOM) decreased by about 50% in Cliff and Cougar Creeks and increased in Dunce and Goat Creeks from 1990 to 1991 (Fig. 6). BOM percent (%) charcoal was similar between years for Cliff and Cougar Creeks, increased fourfold in Dunce Creek, and decreased in Goat Creek.

Macroinvertebrate Community Analysis: Mean abundance in Cliff

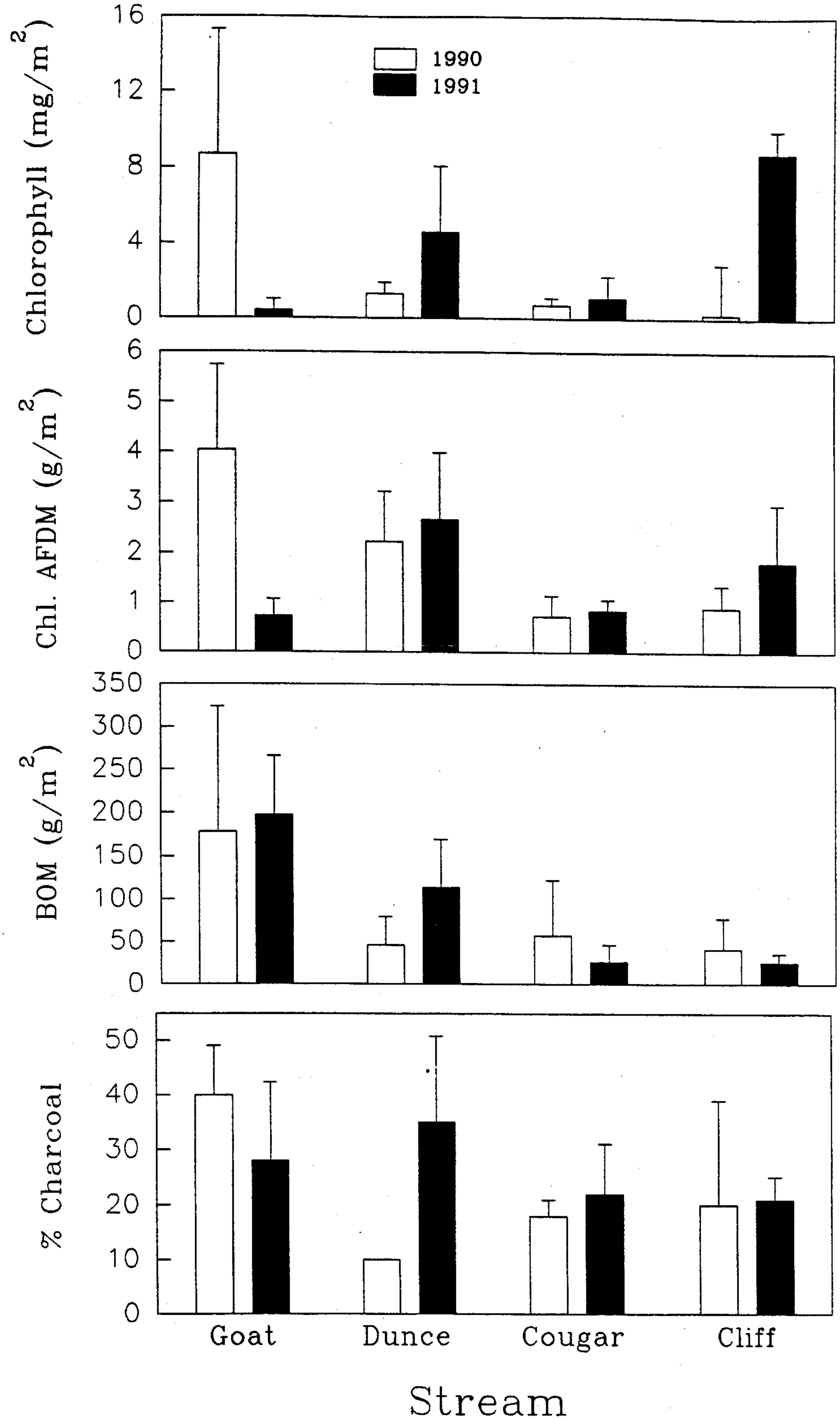


Fig. 6. Periphyton chlorophyll a (mg/m^2), chlorophyll Ash–Free–Dry–Mass (g/m^2), benthic organic matter (g/m^2), and percent charcoal in burn streams in 1990 and 1991. Vertical bars represent one standard deviation from the mean (n=5).

Creek decreased from 4839 individuals/m^2 in 1990 to 2870 individuals/m^2 in 1991 (Fig. 7). However, mean abundance increased slightly in Dunce, Cougar, and Goat Creeks from 1990 to 1991. In contrast, mean biomass increased from 1990 to 1991 in Cliff and Goat Creeks, but decreased in Dunce and Cougar Creeks. Biomass was 2-3X greater in Cliff and Goat Creeks than in Cougar and Dunce Creeks in 1991 (Fig. 7).

Species richness was greatest in Cliff Creek and lowest in Dunce Creek for both years (Fig. 7). All streams had similar species richness in 1990 and 1991. Cliff, Cougar, and Goat Creeks displayed similar patterns in dominance and diversity within and between years. Simpson's index was higher in 1991 for Cliff, Cougar and Goat Creeks compared to 1990 (Fig. 8). However, Dunce Creek displayed a higher dominance value in 1990 relative to 1991. Diversity was lower in 1991 than in 1990 for all streams except Dunce Creek. Diversity was lowest in Cliff Creek and highest in Dunce Creek in 1991.

Temporal patterns in absolute and relative abundance and biomass for functional feeding groups were similar in all four streams. Predator abundance and biomass decreased from 1990 to 1991 in all streams with the exception of biomass in Goat Creek (Table 8). Gatherer abundance and biomass also declined in all streams from 1990 to 1991. Scraper abundance and biomass increased in Goat and Dunce Creeks and decreased in Cliff Creek. Scraper abundance remained unchanged and biomass increased slightly in Cougar Creek. Shredder abundance and biomass were unchanged in Cliff Creek, decreased slightly in Cougar Creek and decreased dramatically in Goat Creek from 1990 to 1991. Shredder numbers increased and biomass decreased over the two-year period in Dunce Creek. Filterer abundance and biomass decreased in Cliff and Goat Creeks, and increased in Dunce Creek. Filterer biomass decreased and abundance increased in Cougar Creek. Miner numbers and biomass increased from 1990 to 1991 in Cliff, Cougar and Goat creeks. Miner biomass decreased and abundance increased from 1990 to 1991 in Dunce Creek (Table 8).

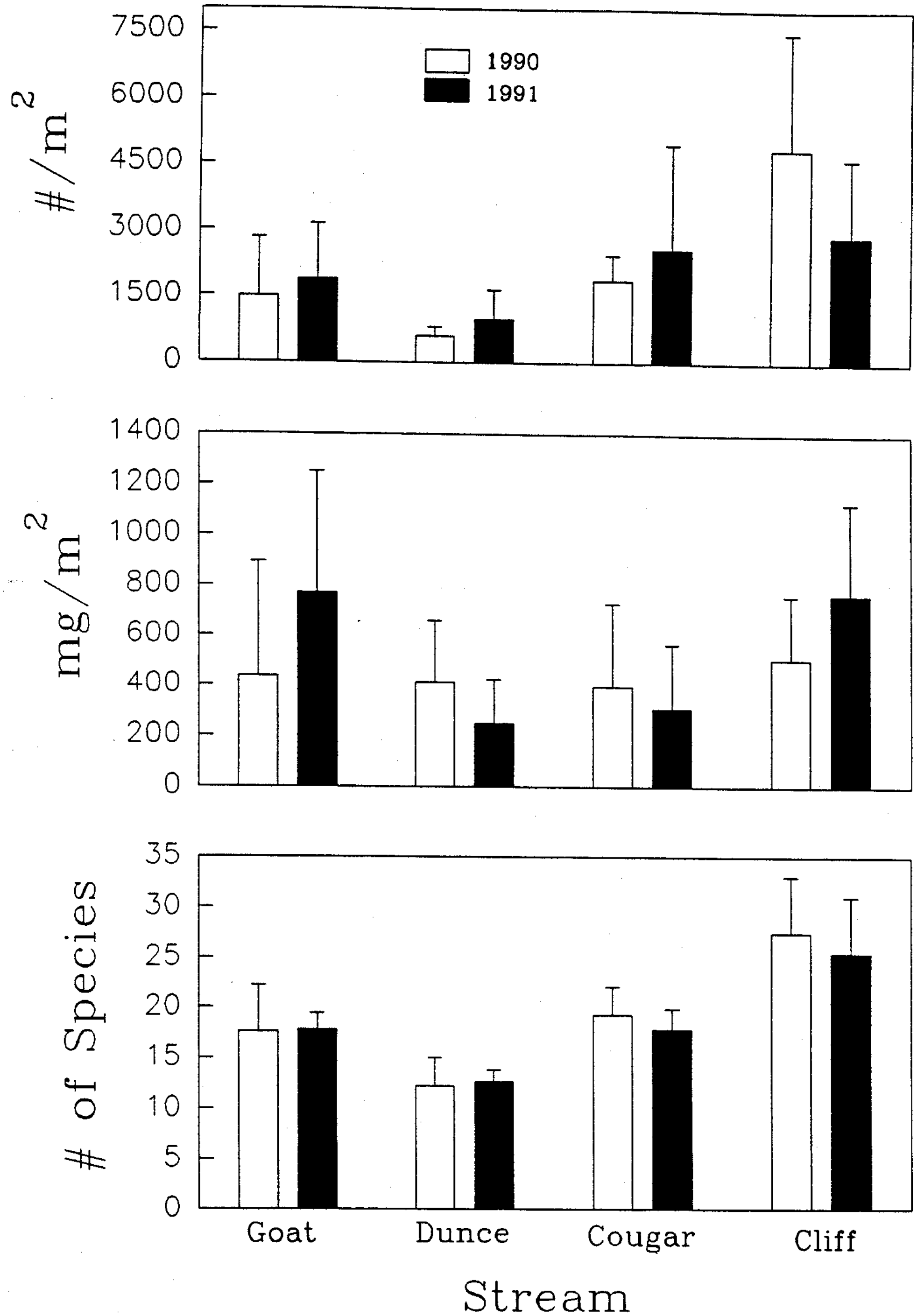


Fig. 7. Mean macroinvertebrate abundance, biomass, and richness collected in four burned streams in 1990 and 1991. Vertical bars represent one standard deviation from the mean.

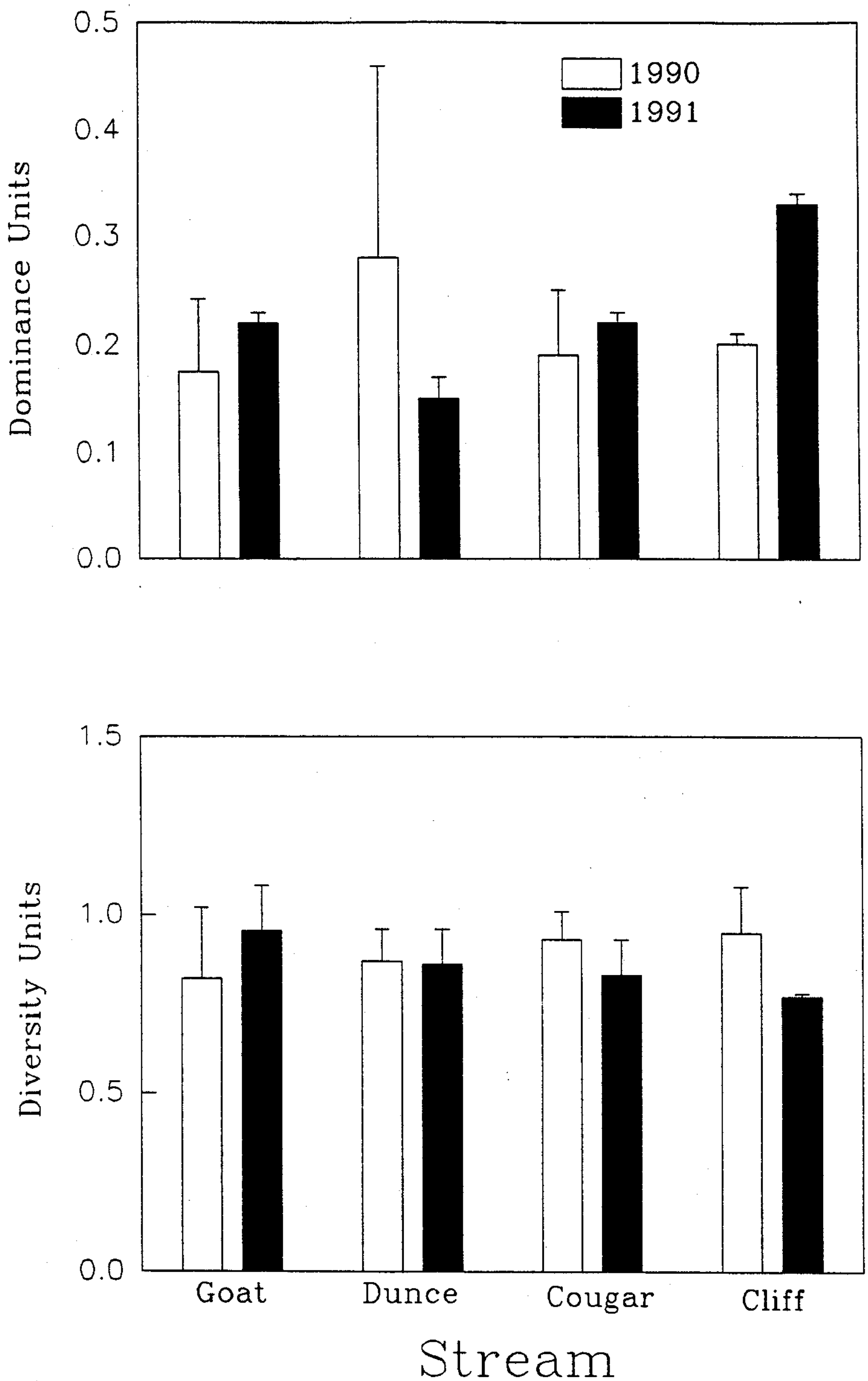


Fig 8. Macroinvertebrate Simpson's Dominance and Shannon–Weiner Diversity for four burned streams sampled in 1990 and 1991. Vertical bars represent one standard deviation from the mean.

Table 8. Mean and relative abundance (#/m2) and biomass (mg/m2) of macroinvertebrate functional feeding groups for Cliff, Cougar, Dunce, and Goat Creeks in 1990 and 1991.

	CLIFF				COUGAR				DUNCE				GOAT			
	1990		1991		1990		1991		1990		1991		1990		1991	
FFG	Mean	Rel. %	Mean	Rel. %	Mean	Rel. %	Mean	Rel. %	Mean	Rel. %	Mean	Rel. %	Mean	Rel. %	Mean	Rel. %
ABUNDANCE																
Predator	667.9	14.1	224.1	12.7	224.1	12.7	147.3	5.7	125.9	21.1	153.9	15.9	288.1	16.2	254	14.6
Gatherer	761.8	14.5	275.3	15.6	629.5	32.9	264.6	10.3	157.9	27.0	145.1	15.0	384.1	24.1	91.8	5.3
Scraper	1195.1	29.1	384.1	21.7	486.6	25.2	646.6	25.1	25.6	4.5	59.8	6.1	66.1	4.8	119.5	6.8
Shredder	138.7	2.4	47.0	2.7	79.0	4.0	106.7	4.1	136.6	22.0	57.6	5.9	132.3	8.0	25.6	1.5
Filterer	337.2	8.3	100.3	5.7	79.0	5.2	277.4	10.7	19.1	7.2	292.4	30.2	571.9	26.7	373.5	21.4
Miner	1720.0	30.5	736.2	41.7	326.5	18.5	1139.6	44.2	89.6	17.4	260.4	26.9	292.4	17.8	881.3	50.5
BIOMASS																
Predator	88.7	15.1	83.2	12.7	41.3	17.0	69.1	22.8	6.9	3.9	46.1	18.7	27.2	5.1	107.9	17.6
Gatherer	162.8	24.2	102.2	15.6	75.4	31.2	22.2	7.3	147.1	34.4	25.9	10.5	108.0	28.7	24.9	4.1
Scraper	182.5	28.3	142.6	21.8	53.9	16.3	127.0	41.8	2.1	1.5	40.8	16.5	2.9	1.4	19.2	3.1
Shredder	10.4	1.9	17.4	2.7	25.9	5.9	10.8	3.6	41.7	7.9	55.9	22.7	58.0	16.8	3.7	0.6
Filterer	111.9	14.8	37.2	5.7	112.1	13.0	31.5	10.4	8.5	6.0	22.1	9.0	31.6	11.3	33.9	5.5
Miner	58.3	8.8	273.3	41.7	8.8	5.1	43.0	14.2	197.8	45.5	56.0	22.7	198.1	32.5	425.2	69.2

Macroinvertebrate Taxa Analysis: No major trends occurred between years for macroinvertebrate taxa. The ten most abundant macroinvertebrate taxa in each stream comprised over 85% of the assemblage collected in July 1990 and 1991 (Table 9). *Suwallia*, Chironomidae, *Heterlimnius*, and Oligochaeta were collected in all streams during both years. Two scrapers, *Drunella doddsi* and *Cinygmula*, were abundant only in Cliff Creek. The 1991 macroinvertebrate data confirm the differences observed among burn streams sampled in 1990.

Big Creek Study: Burn versus Reference Streams

Chemical and Physical Measurements: Three streams within the Big Creek catchment impacted by the 1988 Sliver Creek Fire were sampled in 1991 (Fig. 1). Crooked, Packhorse, and Sliver Creeks were 500-700 meters higher in altitude than other Big Creek streams previously sampled (Table 10). Packhorse and Sliver Creeks were 2nd order streams like Goat and Dunce Creeks with similar link magnitude and discharge. Slopes were greater at Goat and Dunce Creeks. Crooked Creek was similar to Cougar and Cliff Creeks in size and discharge.

Cliff, Goat, Dunce, and Cougar, in addition to Crooked, Packhorse, and Sliver Creeks were compared to reference Main Cave Creek at the mouth, West Fork Cave Creek, Pioneer Creek, and Upper Pioneer Creek. Baseflow discharge was 0.09-0.18 m^3/s in burn streams and 0.01-0.31 m^3/s in reference streams (Table 10). The pH of all burn streams except Cougar Creek was within 0.2 units of the reference streams. Specific conductance in Goat and Dunce Creeks was high and similar to that of WF Cave Creek, while specific conductance in the larger Cliff and Cougar Creeks was intermediate and closer to Pioneer and Upper Pioneer Creeks. Total hardness and alkalinity followed no discernible pattern among burn and reference streams (Table 10). All measures of ionic concentration were lower in the higher elevation Sliver

Table 9. Means, standard deviations (SD), and relative percentages (%) of the densities (#/m2) of the 10 most abundant invertebrate taxa collected at Cliff, Cougar, Dunce and Goat Creeks in 1990 and 1991.

TAXA	CLIFF						COUGAR						DUNCE						GOAT					
	1990			1991			1990			1991			1990			1991			1990			1991		
	Mean	SD	%	Mean	SD	%	Mean	SD	%	Mean	SD	%	Mean	SD	%	Mean	SD	%	Mean	SD	%	Mean	SD	%
Baetis spp.	864	1030	18	225	148	8	316	152	17	555	409	20	19	21	3				45	67	3	109	95	6
Ceratopogonidae										85	84	1	73	145	12				56	118	3			
Chironomidae	864	1275	18	143	52	5	245	149	13	275	320	10	47	44	8	87	100	9	143	137	8	373	282	19
Chironomidae pupae	137	109	3																					
Cinygmula sp.	203	249	4	86	78	3																		
Drunella doddsi				36	17	1																		
Epeorus longimanus										64	60	1												
Heptageniidae							85	116	5															
Hetelimnius sp.	672	370	14	226	160	8	593	383	32	226	178	10	68	85	12	128	138	13	303	281	17	128	234	7
Hexatoma sp.							49	49	3	53	45	1												
Hydracarina sp.																19	43	2	49	39	3	41	32	2
Narpus sp.													58	102	10	58	82	6						
Neophylax sp.							49	49	3															
Nematoda																68	153	7						
Oligochaeta	706	769	15	1707	1327	59	70	51	4	864	776	30	43	27	7	173	170	18	92	52	5	583	393	32
Ostracoda	151	46	3				51	37	3										463	426	26	109	243	6
Seratella tibalis				33	41	1																60	74	3
Simuliidae	156	195	3	89	46	3				341	570	10				85	50	9				265	322	13
Simuliidae pupae													24	21	4				107	193	6			
Suwallia sp.	327	350	7	90	79	3	73	23	4	64	11	1	36	25	6	38	47	4	77	72	4	120	136	6
Turbellaria sp.																						60	46	3
Yoroperla brevis													79	289	13	30	35	3						
Zapada cinctipes							64	66	4				58	100	10				90	79	5			
Zapada columbiana				34	15	1										179	243	19						
Zapada oregonesis										53	61	1												
TOTAL %			84			93			86			85			85			90			81			97

Table 10. Physical and chemical data for burn and reference streams in 1990 and 1991.

STREAM	TYPE	BASIN	YEAR SAMPLED	SLOPE (%)	ELEVATION (m)	DISCHARGE (m3/s)	(HW/LD)	HWIDTH	(H/L)	(H-L)	HIGHFLOW DEPTH		BASEFLOW DEPTH	
								Mean	Mean	Mean	Mean	CV	Mean	CV
MTHCAVE	REF	BIG CREEK	1990	6	1220	0.31	0.28	6.1	3.5	0.4	0.51	0.34	0.15	0.04
PIONEER	REF	BIG CREEK	1990	3	1165	0.16	0.28	3.4	3.6	0.4	0.56	0.22	0.16	0.28
PIONEER UP	REF	BIG CREEK	1990	6	1485	0.13	0.35	3.2	2.8	0.3	0.42	0.09	0.15	0.26
WFCAVE	REF	BIG CREEK	1990	6	1365	0.01	0.16	1.2	6.4	0.3	0.32	0.26	0.05	0.02
CLIFF	BURN	BIG CREEK	1991	11	1145	0.18	0.34	3.8	2.9	0.3	0.49	0.19	0.17	0.37
GOAT	BURN	BIG CREEK	1991	18	1125	0.09	0.33	0.9	3.1	0.1	0.18	0.34	0.06	0.31
DUNCE	BURN	BIG CREEK	1991	15	1065	0.15	0.33	1.1	3.0	0.2	0.22	0.18	0.07	0.16
COUGAR	BURN	BIG CREEK	1991	12	1095	0.10	0.42	3.1	2.4	0.3	0.45	0.08	0.19	0.33
CROOKED	BURN	BIG CREEK	1991	3	1780	0.17	0.34	4.5	2.9	0.3	0.42	0.12	0.14	0.15
PACKHORSE	BURN	BIG CREEK	1991	4	1780	0.04	0.31	4.1	3.2	0.2	0.28	0.26	0.09	0.14
SLIVER	BURN	BIG CREEK	1991	5	1880	0.04	0.39	2.4	2.6	0.2	0.27	0.16	0.10	0.14
WHIMSTICK EF	BURN	CHAMBERLAIN	1991	2	1745	0.02	0.27	4.6	3.7	0.3	0.39	0.09	0.10	0.15
WHIMSTICK SF	BURN	CHAMBERLAIN	1991	2	1730	0.04	0.48	4.7	2.1	0.2	0.46	0.17	0.22	0.35
WHIMSTICK MAIN	BURN	CHAMBERLAIN	1991	1	1710	0.10	0.39	8.0	2.6	0.4	0.59	0.13	0.23	0.36
MCCALLA E	REF	CHAMBERLAIN	1991	2	1915	0.05	0.48	2.0	2.1	0.2	0.30	0.29	0.14	0.36
MCCALLA 3	REF	CHAMBERLAIN	1991	2	1890	0.05	0.61	1.9	1.6	0.1	0.28	0.22	0.17	0.39
MCCALLA 4	REF	CHAMBERLAIN	1991	2	1820	0.13	0.52	2.4	1.9	0.2	0.43	0.19	0.22	0.33

Table 10 . Cont.

STREAM	TYPE	BASIN	YEAR	SUBSTRATE LENGTH (cm)		ALKALINITY (mg/l CaCO3)	HARDNESS (mg/l CaCO3)	pH	SPECIFIC CONDUCTANCE (uS/cm/s)	ANNUAL TEMP (C)
				Mean	CV					
MTHCAVE	REF	BIG CREEK	1990	18.8	0.65	24	44	7.9	39	15
PIONEER	REF	BIG CREEK	1990	16.7	0.84	62	86	8.1	88	11
PIONEER UP	REF	BIG CREEK	1990	14.6	0.77	56	81	8.1	88	11
WFCAVE	REF	BIG CREEK	1990	4.1	1.12	134	161	8.0	177	9
CLIFF	BURN	BIG CREEK	1991	22.5	0.85	77	71	8.2	73	13
GOAT	BURN	BIG CREEK	1991	10.9	1.46	49	51	8.4	153	10
DUNCE	BURN	BIG CREEK	1991	13.9	1.57	82	78	8.5	168	13
COUGAR	BURN	BIG CREEK	1991	22.6	1.1	36	32	7.4	93	12
CROOKED	BURN	BIG CREEK	1991	14.8	1.16	25	23	8.3	58	15
PACKHOR	BURN	BIG CREEK	1991	12.6	0.65	34	36	8.4	74	17
SLIVER	BURN	BIG CREEK	1991	13.5	0.64	67	63	8.2	49	10
WHIMSTICK EF	BURN	CHAMBERLAIN	1991	9.7	1.43	32	34	8.1	57	13
WHIMSTICK SF	BURN	CHAMBERLAIN	1991	6.7	1.36	31	29	7.7	41	9
WHIMSTICK MAIN	BURN	CHAMBERLAIN	1991	8.7	0.99	20	19	8.6	52	13
MCCALLA E	REF	CHAMBERLAIN	1991	4.2	1.71	38	38	8.4	72	11
MCCALLA 3	REF	CHAMBERLAIN	1991	2.1	2.12	38	38	8.4	73	13
MCCALLA 4	REF	CHAMBERLAIN	1991	4.2	1.17	36	33	8.4	66	17

Table 10 . Cont.

STREAM	TYPE	BASIN	YEAR	CHLOROPHYLL a (ug/cm2)		CHLOROPHYLL AFDM (g/m2)		B/C	BOM (g/m2)	
				Mean	CV	Mean	CV		Mean	CV
MTHCAVE	REF	BIG CREEK	1990	0.86	0.26	3.98	0.45	4.6	17.2	0.63
PIONEER	REF	BIG CREEK	1990	0.28	0.99	1.12	0.26	4.0	7.4	0.45
PIONEER UP	REF	BIG CREEK	1990	0.22	0.87	1.50	0.66	6.8	15.7	0.48
WFCAVE	REF	BIG CREEK	1990	0.59	0.27	3.77	0.49	6.4	45.9	1.41
CLIFF	BURN	BIG CREEK	1991	0.88	0.14	1.81	0.64	2.1	25.6	0.41
GOAT	BURN	BIG CREEK	1991	0.04	1.40	0.73	0.45	17.4	197.1	0.35
DUNCE	BURN	BIG CREEK	1991	0.46	0.76	2.66	0.50	0.6	113.8	0.49
COUGAR	BURN	BIG CREEK	1991	0.11	1.11	0.84	0.26	7.8	25.9	0.80
CROOKED	BURN	BIG CREEK	1991	0.43	0.44	2.16	0.31	5.1	12.0	0.63
PACKHOR	BURN	BIG CREEK	1991	0.34	0.46	1.06	0.59	3.1	28.2	0.73
SLIVER	BURN	BIG CREEK	1991	0.54	0.64	1.31	0.22	0.2	29.2	0.65
WHIMSTICK EF	BURN	CHAMBERLAIN	1991	0.36	0.53	1.43	0.28	4.0	11.3	1.46
WHIMSTICK SF	BURN	CHAMBERLAIN	1991	0.33	0.71	1.36	0.33	4.1	15.7	0.57
WHIMSTICK MAIN	BURN	CHAMBERLAIN	1991	0.20	0.56	1.01	0.48	0.5	24.0	0.56
MCCALLA E	REF	CHAMBERLAIN	1991	0.71	0.78	1.78	0.58	0.3	51.8	0.60
MCCALLA 3	REF	CHAMBERLAIN	1991	0.19	0.94	0.67	0.67	0.4	38.3	1.33
MCCALLA 4	REF	CHAMBERLAIN	1991	0.12	1.32	1.09	0.84	0.9	24.5	1.95

Creek Fire streams than in the lower elevation Golden Fire streams.

Reference streams exhibited a narrower range of annual temperature variation than burn streams except for Main Cave Creek (Table 10). The greater annual temperature at Main Cave Creek results from a broad valley form and open canopy (Robinson and Minshall 1991). The annual temperature range was greater at Sliver Creek Fire sites than at Golden Fire sites.

Smaller streams within burn and reference groups had smaller mean substrate size and higher coefficients of variation (CV's) than larger sized streams (Table 10). For example, substrate length in WF Cave Creek was about 3X's smaller and CV 1-2X's higher than in other reference streams. Substrate sizes in Packhorse and Sliver Creeks were similar to those in Goat and Dunce Creeks, but substrate CV's were lower. The ratio of highflow channel area to baseflow channel area (H/L) was similar among burn and reference streams indicating little channel change resulting from the fires (Table 10).

<u>Periphytic and Benthic Organic Matter:</u> Southern aspect reference streams (Cave Creek) displayed higher chlorophyll <u>a</u> and AFDM than northern aspect reference streams (Pioneer Creek)(Fig. 9). Goat and Cougar Creeks displayed lower values of chlorophyll <u>a</u> and AFDM than all other streams. The B/C ratio, an index of relative autotrophy, varied considerably among burn streams with Goat Creek (17.4) being much higher than other burn streams (Table 10).

There was more benthic organic matter (BOM) in small burn streams than in similar size reference streams (Fig. 9). For example, BOM in Goat Creek was about 4X's higher than in WF Cave Creek. BOM in Sliver Burn sites was comparable to larger streams among Golden Burn sites. BOM % charcoal was substantially greater in burn streams than in reference streams.

<u>Macroinvertebrate Community Analysis:</u> Mean macroinvertebrate

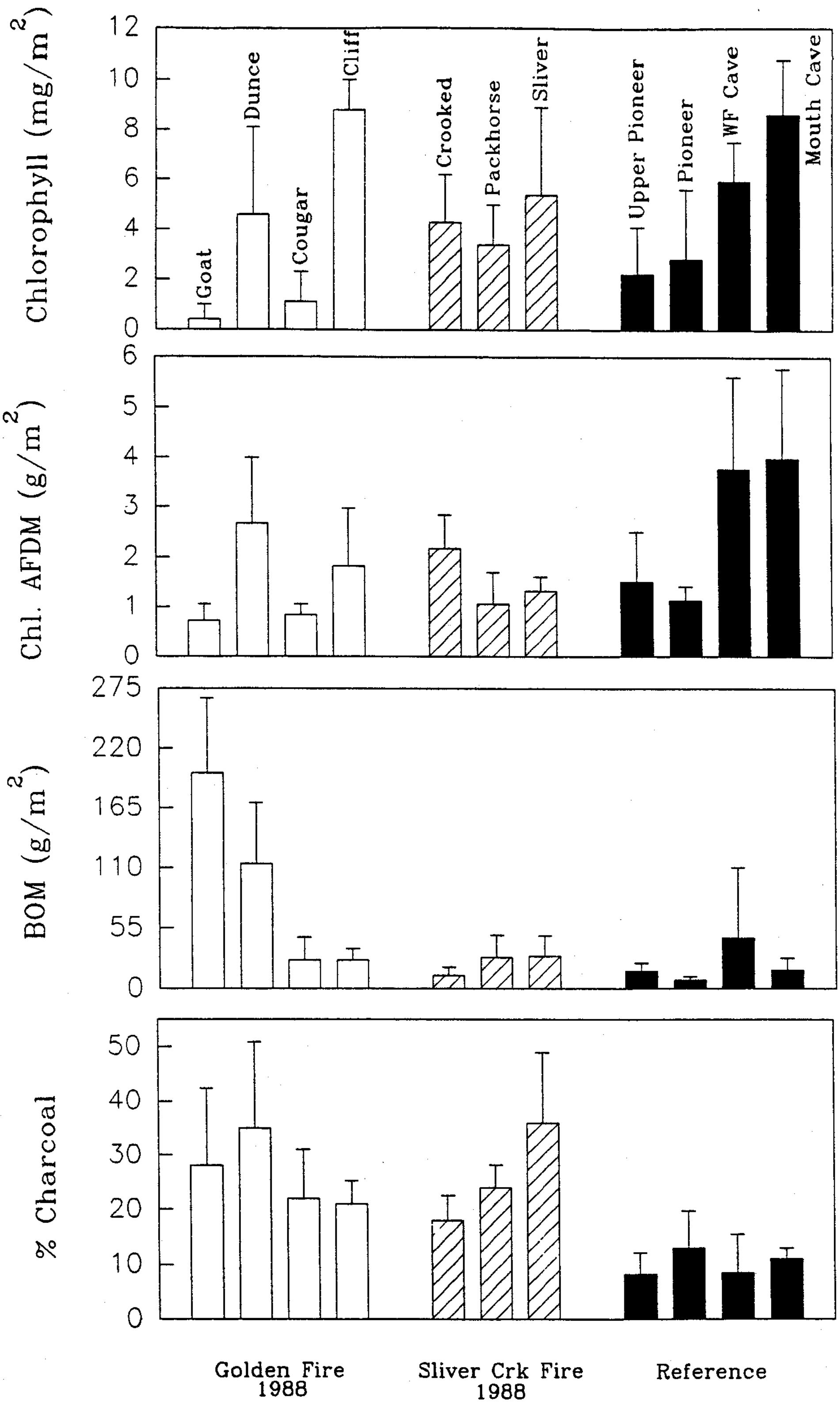


Fig. 9. Mean periphyton chlorophyll a (mg/m^2), chlorophyll Ash–Free–Dry–Mass (g/m^2), benthic organic matter (g/m^2) and % charcoal in burn and reference streams. Vertical bars represent one standard deviation from the mean. (n=5).

abundance tended to be less in burn, especially in Golden Fire streams, than in reference streams (Fig. 10). Mean abundance ranged from 966 (Dunce Creek) to 6158 individuals/m^2 (Sliver Creek) for burn streams, and from 4368 (Pioneer Creek) to 9304 individuals/m^2 (Main Cave Creek) in reference streams. Mean biomass displayed no pattern between burned and reference sites. Biomass was lowest in Dunce Creek (246 mg/m^2) and greatest in Sliver Creek (1223 mg/m^2) among burn streams. Upper Pioneer Creek had the greatest biomass (1457 mg/m^2) and WF Cave Creek the lowest (466 mg/m^2) among reference streams (Fig. 10).

Species richness values also varied greatly and were typically less in burn sites relative to comparably sized reference sites. Dunce Creek had the fewest taxa (12) and Sliver Creek the most (27) among burn streams. Mean species richness in reference sites varied from 21 species in Pioneer Creek to 31 species in Main Cave Creek (Fig. 10).

Shannon's diversity and Simpson's dominance showed no trends between burn and reference streams (Fig. 11). Diversity among burn streams was greatest in Sliver Creek and lowest in Cliff Creek, while dominance was lowest in Dunce Creek and greatest in Cliff Creek. Diversity in reference sites was greatest in Upper Pioneer Creek and lowest in WF Cave Creek. Dominance was greatest in Pioneer Creek and least in Upper Pioneer Creek.

<u>Macroinvertebrate Taxa Analysis:</u> Taxa differences were expected for organisms whose food sources were altered by fire. Periphyton biomass should increase in streams in which the overhead riparian canopy is destroyed because of greater light input and possible increases in temperature. Gatherers and scrapers, using periphyton as food, should be affected and display associated increases in abundance and biomass. The gatherer *Baetis* was abundant in all burn streams except Dunce Creek (Table 11). The gathering mayfly *Serratella tibialis* was abundant in Crooked, Goat and Cliff Creeks. The scraper *Cinygmula* and gatherer *Drunella doddsi* were abundant in Cliff,

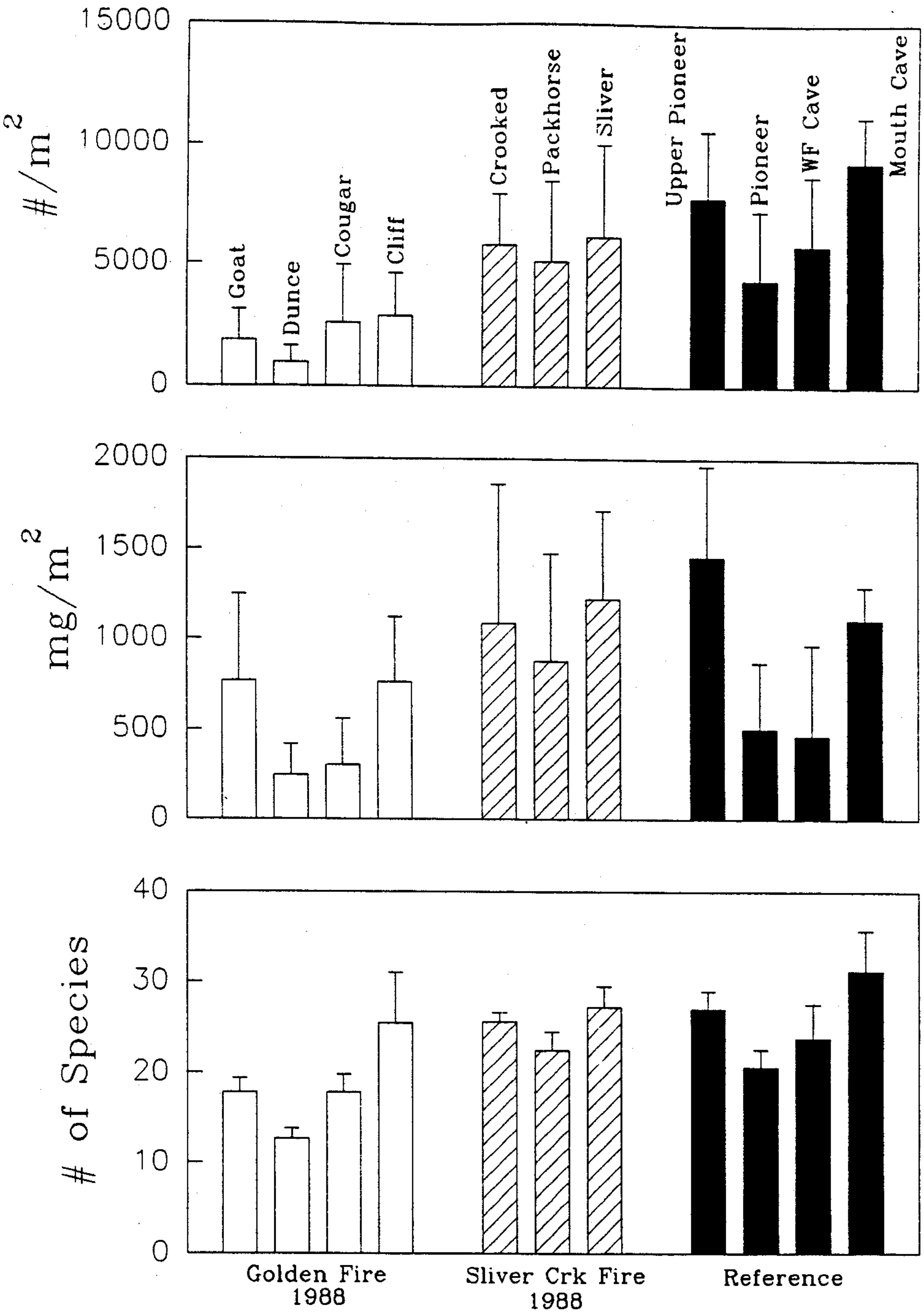


Fig. 10. Mean macroinvertebrate abundance, biomass, and richness for burned and reference streams in the Big Creek drainage. Vertical bars represent one standard deviation from the mean (n=5).

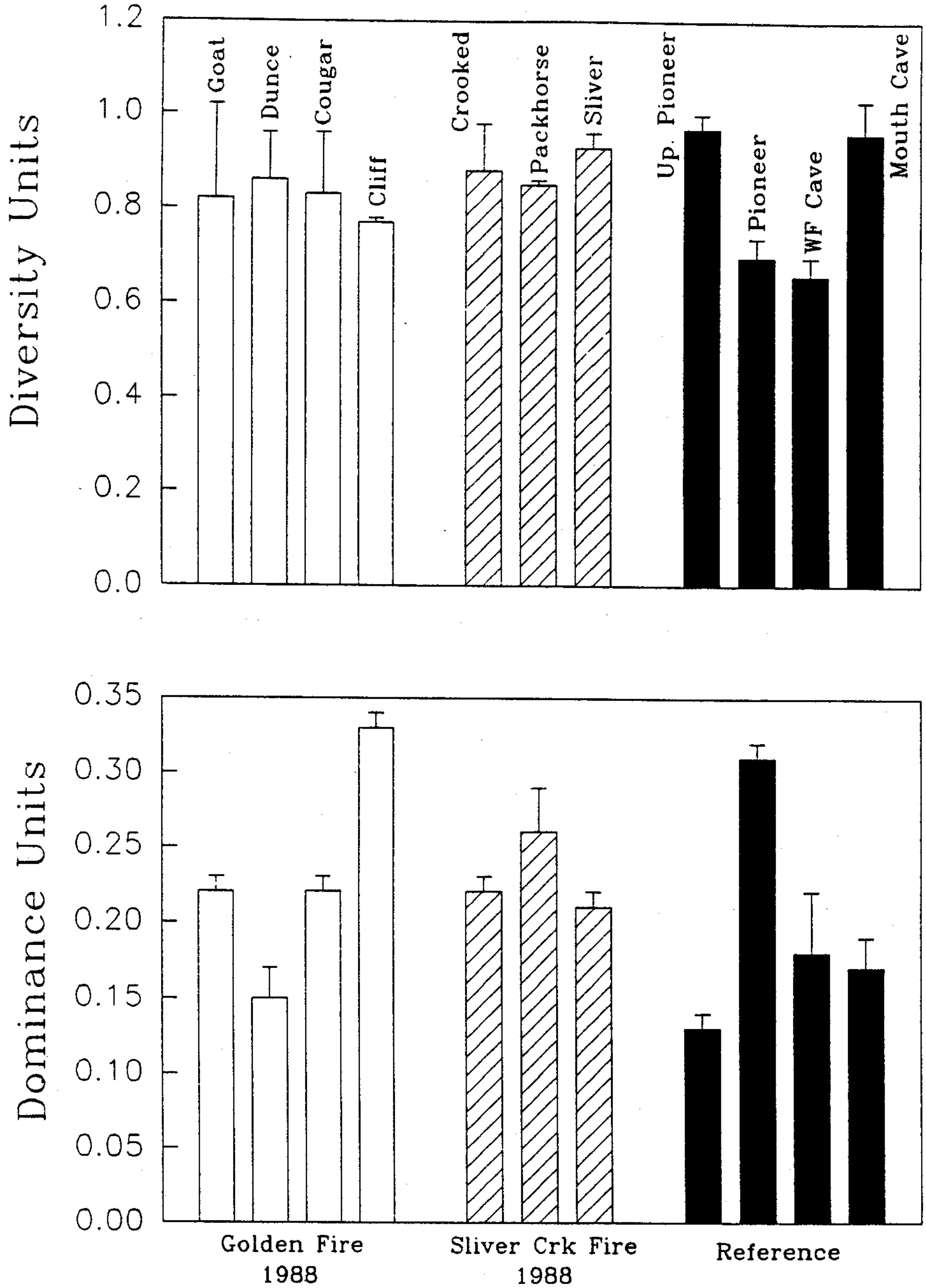


Fig 11. Mean macroinvertebrate values for Shannon–Weiner Diversity and Simpson's Dominance for burned and reference streams in the Big Creek drainage. Vertical bars represent one standard deviation from the mean (n=5).

Table 11. Absolute and relative density (#/m2) of top ten macroinvertebrate taxa for burn (1991) and reference (1990, 1991) streams in Big Creek and Chamberlain basins.

CLIFF (1991)	BURN		
	Absolute		Relative (%)
taxa	MEAN	SD	
Oligochaeta	1707	1323	59.3
Baetis bicaudatus	224	148	7.8
Heterlimnius sp.	224	160	7.8
Chironomidae	139	52	4.8
Suwallia sp.	96	79	3.3
Simulium	85	46	3.0
Cinygmula sp.	85	78	3.0
Drunella doddsi	32	17	1.1
Zapada columbiana	32	15	1.1
Serratella tibialis	32	41	1.1

UPPER PIONEER (1990)	REFERENCE		
	Absolute		Relative (%)
taxa	MEAN	SD	
Oligochaeta	2535	2314	28.5
Chironomidae	1001	335	11.3
Rhithrogena sp.	818	469	9.2
Zapada columbiana	425	657	4.8
Rhyocophila vespula	421	261	4.7
Baetis bicaudatus	420	232	4.7
Turbellaria	403	575	4.5
Rhyacophila vagrita	366	191	4.1
Suwallia sp.	350	423	3.9
Cinygmula sp.	273	240	3.1

GOAT (1991)	BURN		
	Absolute		Relative (%)
taxa	MEAN	SD	
Oligochaeta	583	393	29.6
Chironomidae	373	282	19.0
Simulium	265	322	13.5
Heterlimnius	128	234	6.5
Ostracoda	120	136	6.1
Suwallia	119	136	6.0
Baetis bicaudatus	109	243	5.5
Serratella tibialis	109	95	5.5
Turbellaria	60	74	3.0
Hydracarina	60	46	3.0

PIONEER (1990)	REFERENCE		
	Absolute		Relative (%)
taxa	MEAN	SD	
Oligochaeta	1207	1579	27.6
Chironomidae	656	585	15.0
Cinygmula sp.	501	813	11.5
Baetis bicaudatus	156	134	3.6
Dixa sp.	131	0	3.0
Heterlimnius sp.	127	167	2.9
Calineuria	115	134	2.6
Drunella flavilinea	107	43	2.4
Epeorus longimanus	92	66	2.1
Rhyacophila hyalinata	83	0	1.9

DUNCE (1991)	BURN		
	Absolute		Relative (%)
taxa	MEAN	SD	
Zapada columbiana	179	243	18.5
Oligochaeta	173	170	17.9
Heterlimnius sp.	128	138	13.2
Chironomidae	87	101	9.1
Simulium	85	51	8.8
Nematoda	68	153	7.1
Narpus sp.	58	82	6.0
Suwallia sp.	38	47	4.0
Yoroperla brevis	30	35	3.1
Hydracarina	19	43	2.0

MOUTH CAVE (1990)	REFERENCE		
	Absolute		Relative (%)
taxa	MEAN	SD	
Oligochaeta	2162	642	23.2
Heterlimnius sp.	2115	1062	22.7
Chironomidae	1449	435	15.6
Ostracoda	745	759	8.0
Hydracarina	623	446	6.7
Baetis intermedius	538	302	5.8
Suwallia sp.	243	219	2.6
Isoperla sp.	237	129	2.5
Chironomidae pupae	235	111	2.5
Serratella tibialis	107	43	1.1

COUGAR (1991)	BURN		
	Absolute		Relative (%)
taxa	MEAN	SD	
Oligochaeta	864	754	28.1
Baetis intermedius	555	409	18.0
Simulium	341	570	11.1
Chironomidae	275	324	8.9
Heterlimnius sp.	226	178	7.4
Ceratopogonidae	85	92	2.8
Suwallia sp.	64	11	2.1
Epeorus longimanus	64	67	2.1
Hexatoma sp.	53	45	1.7
Zapada oregonesis	53	61	1.7

WEST FORK CAVE (1990)	REFERENCE		
	Absolute		Relative (%)
taxa	MEAN	SD	
Ostracoda	1569	686	27.0
Heterlimnius	1125	699	19.3
Chironomidae	918	1188	15.8
Yoroperla brevis	758	294	13.0
Oligochaeta	263	319	4.5
Rhyacophila vespula	158	86	2.7
Nematoda	134	236	2.3
Suwallia sp.	120	95	2.1
Paraleptophlebia sp.	90	88	1.5
Hydracarina	79	50	1.4

Table 11. cont.

CROOKED (1991)	BURN		
	Absolute		Relative (%)
taxa	MEAN	SD	
Oligochaeta	2108	1094	42.1
Chironomidae	1547	594	30.9
Baetis intermedius	397	225	7.9
Heterlimnius sp.	327	268	6.5
Epeorus longimanus	232	224	4.6
Serratella tibialis	158	83	3.2
Hydrocarina	122	82	2.4
Rhyacophila hyalinata	115	70	2.3
Isoperla	90	130	1.8
Rhyacophila vespula	90	112	1.8

MAIN WHIMSTICK (1991)	BURN		
	Absolute		Relative (%)
taxa	MEAN	SD	
Oligochaeta	1189	1315	39.7
Heterlimnius	546	511	18.2
Baetis bicaudatus	397	245	13.3
Cinygmula sp.	181	200	6.1
Chironomidae	166	147	5.6
Drunella colordensis	90	60	3.0
Serratella tibialis	83	111	2.8
Simulium	77	80	2.6
Suwallia sp.	43	35	1.4
Megarcys	32	44	1.1

PACKHORSE (1991)	BURN		
	Absolute		Relative (%)
taxa	MEAN	SD	
Oligochaeta	1945	1153	31.4
Chironomidae	1107	542	17.9
Baetis intermedius	672	665	10.9
Heterlimnius	336	644	5.4
Baetis bicaudatus	309	437	5.0
Parapsyche	277	205	4.5
Hydracarina	245	141	4.0
Drunella doddsi	226	143	3.6
Cinygmula sp.	203	170	3.3
Drunella sp.	141	157	2.2

EF McCALLA (1991)	REFERENCE		
	Absolute		Relative (%)
taxa	MEAN	SD	
Oligochaeta	4059	1834	28.7
Chironomidae	1927	2389	13.6
Baetis intermedius	1630	1570	11.5
Yoroperla brevis	1504	675	10.6
Micrasema sp.	1187	1568	8.4
Simulium	933	436	6.6
Ostracoda	563	919	4.0
Hydracarina	527	540	3.7
Heterlimnius	252	208	1.8
Cinygmula sp.	250	155	1.8

SLIVER (1991)	BURN		
	Absolute		Relative (%)
taxa	MEAN	SD	
Oligochaeta	1605	1622	26.0
Baetis intermedius	1408	1643	22.8
Yoroperla brevis	617	297	10.0
Chironomidae	461	466	7.5
Ostracoda	388	643	6.3
Parapsyche	318	415	5.2
Hydracarina	213	259	3.5
Cinygmula sp.	130	115	2.1
Drunella sp.	105	127	1.7
Rhyacophila acropedes	87	71	1.4

McCALLA 3o ORDER (1991)	REFERENCE		
	Absolute		Relative (%)
taxa	MEAN	SD	
Baetis intermedius	395	370	14.6
Oligochaeta	386	272	14.3
Yoroperla brevis	305	258	11.3
Simulium	211	220	7.8
Micrasema sp.	194	291	7.2
Heterlimnius	192	294	7.1
Chironomidae	181	196	6.7
Hydracarina	160	192	5.9
Ostracoda	120	255	4.4
Turbellaria	92	96	3.4

EF WHIMSTICK (1991)	BURN		
	Absolute		Relative (%)
taxa	MEAN	SD	
Heterlimnius	610	309	21.7
Baetis intermedius	551	494	19.6
Oligochaeta	464	491	16.5
Cinygmula sp.	201	96	7.1
Chironomidae	158	82	5.6
Drunella flavilinea	104	53	3.7
Drunella sp.	91	58	3.2
Suwallia sp.	79	44	2.8
Optioservus sp.	64	30	2.3
Hydracarina	60	41	2.1

McCALLA 4TH ORDER (1991	REFERENCE		
	Absolute		Relative (%)
taxa	MEAN	SD	
Heterlimnius	2012	642	26.4
Oligochaeta	1598	786	20.9
Chironomidae	1090	402	14.3
Baetis intermedius	625	138	8.2
Serratella tibialis	318	159	4.2
Cinygmula sp.	292	52	3.8
Ostracoda	213	425	2.8
Drunella sp.	194	147	2.5
Yoroperla brevis	179	77	2.3
Micrasema sp.	149	100	2.0

SF WHIMSTICK (1991)	BURN		
	Absolute		Relative (%)
taxa	MEAN	SD	
Baetis bicaudatus	849	759	20.8
Cinygmula sp.	580	553	14.2
Chironomidae	572	762	14.0
Yoroperla brevis	474	359	11.6
Oligochaeta	378	446	9.2
Heterlimnius	228	153	5.6
Hydrocarina	141	209	3.4
Serratella tibialis	117	188	2.9
Simulium	115	189	2.8
Micrasema sp.	111	207	2.7

Sliver and Packhorse Creeks. *Baetis* was abundant in all reference streams except WF Cave Creek. *Cingymula* was abundant in reference Upper Pioneer and Pioneer Creeks, and *Serratella tibialis* was abundant at Main Cave Creek. Shredding detritivores, dependent on leaf litter input, also should display fire affects because of reduced riparian inputs following fire. Burn streams with abundant shredders included Sliver Creek (*Yoroperla brevis*: 617 individuals/m^2), Cliff Creek (*Zapada columbiana*: 32 individuals/m^2), Dunce Creek (*Zapada columbiana* and *Yoroperla brevis*: 179 and 30 individuals/m^2, respectively), and Cougar Creek (*Zapada oregonensis*: 53 individuals/m^2). Shredders were among the ten most abundant taxa in reference Upper Pioneer (*Zapada columbiana*: 425 individuals/m^2) and WF Cave (*Yoroperla brevis*: 758 individuals/m^2) Creeks (Table 11).

Golden Fire versus Sliver Creek Fire

<u>Chemical and Physical Measurements:</u> Streams in Chamberlain Basin were comparable to Big Creek streams for most geomorphic factors (Table 10). However, Golden Fire streams generally were higher gradient than streams impacted by the Sliver Fire. This difference in slope between streams impacted by either fire is a likely factor contributing to other physical differences and subsequent recovery dynamics. For instance, substrates tended to be smaller in Chamberlain Basin streams, perhaps because fine sediments were not flushed by high flows. Burn streams in Chamberlain Basin showed evidence of increased channel down-cutting relative to reference streams, whereas respective streams in Big Creek catchment did not show this effect. Ionic concentrations tended to be lower and pH higher in Chamberlain Basin streams (Table 10). Annual temperature ranges were similar between basins.

<u>Periphytic and Benthic Organic Matter:</u> Periphytic and benthic

organic matter did not exhibit marked differences between Big Creek catchment and Chamberlain Basin streams, although smaller open canopied sites displayed somewhat greater periphyton levels. Within the Big Creek catchment, periphyton chlorophyll a and AFDM tended to be greater and BOM lower for Sliver Creek Fire streams than Golden Fire streams (Fig. 9). Stream temperatures and solar input were greater (i.e. more open canopy) in the Sliver Creek Fire streams than in Golden Fire streams (Table 10). The range of values was broader in Big Creek streams than Chamberlain Basin streams; for example, BOM ranged from 7.4 to 197.1 g/m^2 in Big Creek streams and only from 11.3 to 51.8 g/m^2 in Chamberlain Basin streams. BOM % charcoal was greater in Big Creek catchment burn streams than in reference streams, although Chamberlain Basin reference streams also had relatively high BOM % charcoal (Fig. 9, 12).

Macroinvertebrate Community Analysis: Abundances tended to be lower in Chamberlain Basin streams than in Big Creek catchment streams, perhaps because of lower gradient and smaller substrate sizes (less available habitat) in Chamberlain Basin streams. Sliver Creek Fire streams within Big Creek catchment had larger values for most community parameters compared to those of the Golden Fire streams (Fig. 10). Mean macroinvertebrate abundance in Sliver Fire streams within Big Creek catchment ranged from 5151 individuals/m^2 in Packhorse Creek to 6158 individuals/m^2 in Sliver Creek (Fig. 10). Abundances in streams impacted by the Golden Fire ranged from a relatively low 966 individuals/m^2 in Dunce Creek to 2870 individuals/m^2 in Cliff Creek. Mean biomass displayed a similar response pattern as abundance, however biomass was similar between basins (Fig. 10, 13). Biomass in Sliver Creek Fire streams within Big Creek catchment ranged from 879 mg/m^2 in Packhorse Creek to 1223 mg/m^2 in Sliver Creek (Fig. 10). Mean biomass in Golden Fire streams ranged from 246 mg/m^2 in Dunce Creek to 768 mg/m^2 in Goat Creek.

Species richness tended to be lower in burn streams than

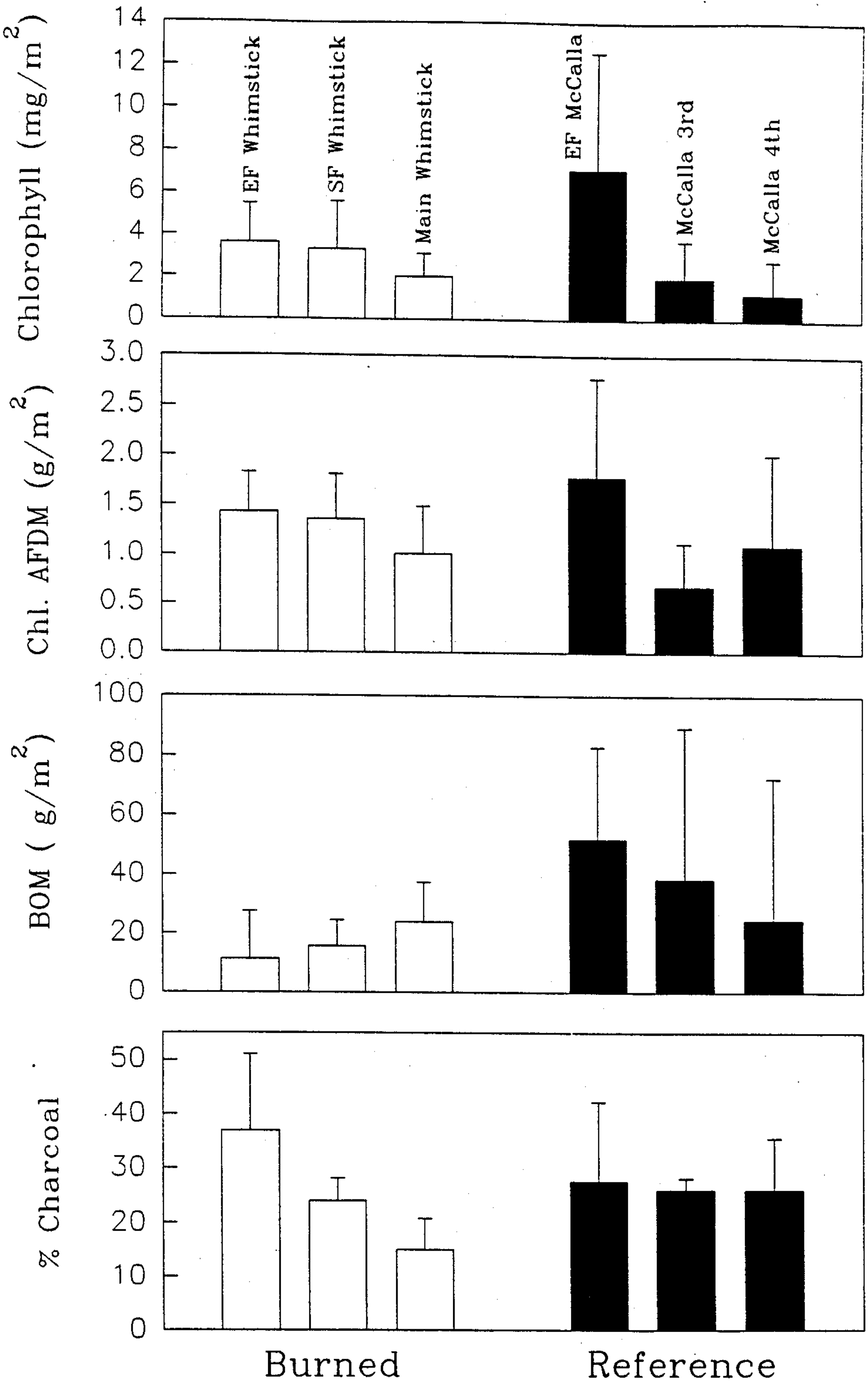


Fig. 12. Mean periphyton chlorophyll a (mg/m^2), chlorophyll Ash-Free-Dry-Mass (g/m^2), benthic organic matter (g/m^2) and percent charcoal in burn and reference streams in the Chamberlain basin. Vertical bars represent one standard deviation from the mean (n=5).

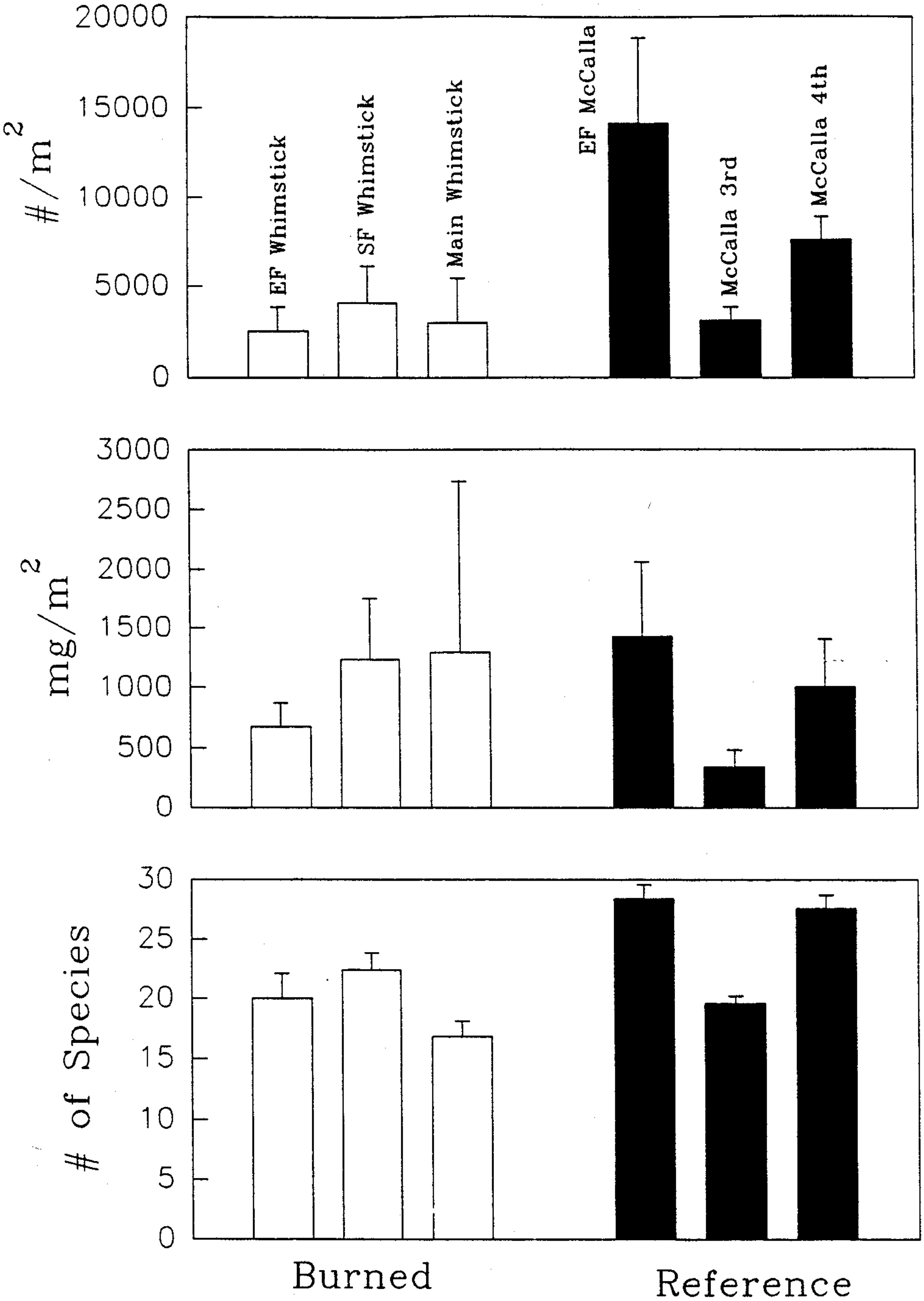


Fig. 13. Mean macroinvertebrate abundance, biomass, and richness of burned and reference streams sampled in the Chamberlin Basin in 1991. Vertical bars represent one standard deviation (n=5).

reference streams for both basins. Species richness was higher in Sliver Creek Fire streams within Big Creek catchment than in Golden Fire streams except for Cliff Creek (Fig. 10). Richness ranged from 22 to 27 species in Sliver Creek Fire streams. Golden Fire streams showed wide fluctuations in richness. For example, richness in Goat, Cougar, and Dunce Creeks ranged from 12 to 17 species. However, Cliff Creek displayed richness values (25 species) similar to those of Sliver Creek Fire streams. Recall that Cliff Creek was sampled outside the fire perimeter, thus riparian vegetation was more similar to Sliver Creek Fire streams than to Golden Fire streams.

Shannon-Weiner diversities were similar and Simpson's dominance values lower in Chamberlain Basin streams than in Big Creek catchment streams (Fig. 11, 14). Diversity and dominance were lower in Golden Fire streams than in Sliver Creek Fire streams within Big Creek catchment, except dominance was substantially greater in Cliff Creek than all others streams (Fig. 11). Dominance ranged from 0.15 in Dunce Creek to 0.33 in Cliff Creek for Golden Fire streams, while dominance ranged from 0.21 to 0.26 in Sliver Creek Fire streams.

Macroinvertebrate Taxa Analysis: Oligochaeta and Chironomidae were abundant in all streams (Table 11). Oligochaeta (miner), Chironomidae (miner), Simuliidae (filterer), and *Heterlimnius* (scraper) were found consistently in Golden Fire streams. Golden Fire streams had 2 abundant predator taxa. *Suwallia* occurred in all Golden Fire sites except Goat Creek, while Hydracarina occurred only in Goat and Dunce Creeks. The predators turbellaria and *Hexatoma* were abundant in Goat and Cougar Creeks, respectively. The shredder *Zapada* was abundant in Cliff, Dunce, and Cougar Creeks, and *Yoroperla brevis* was abundant only in Dunce Creek. The presence of shredders suggests some recovery of riparian vegetation. Gatherers and scrapers were common in Golden Fire streams. *Baetis* was abundant in Cliff, Goat, and Cougar Creeks. *Serratella tibialis* was abundant in Cliff and

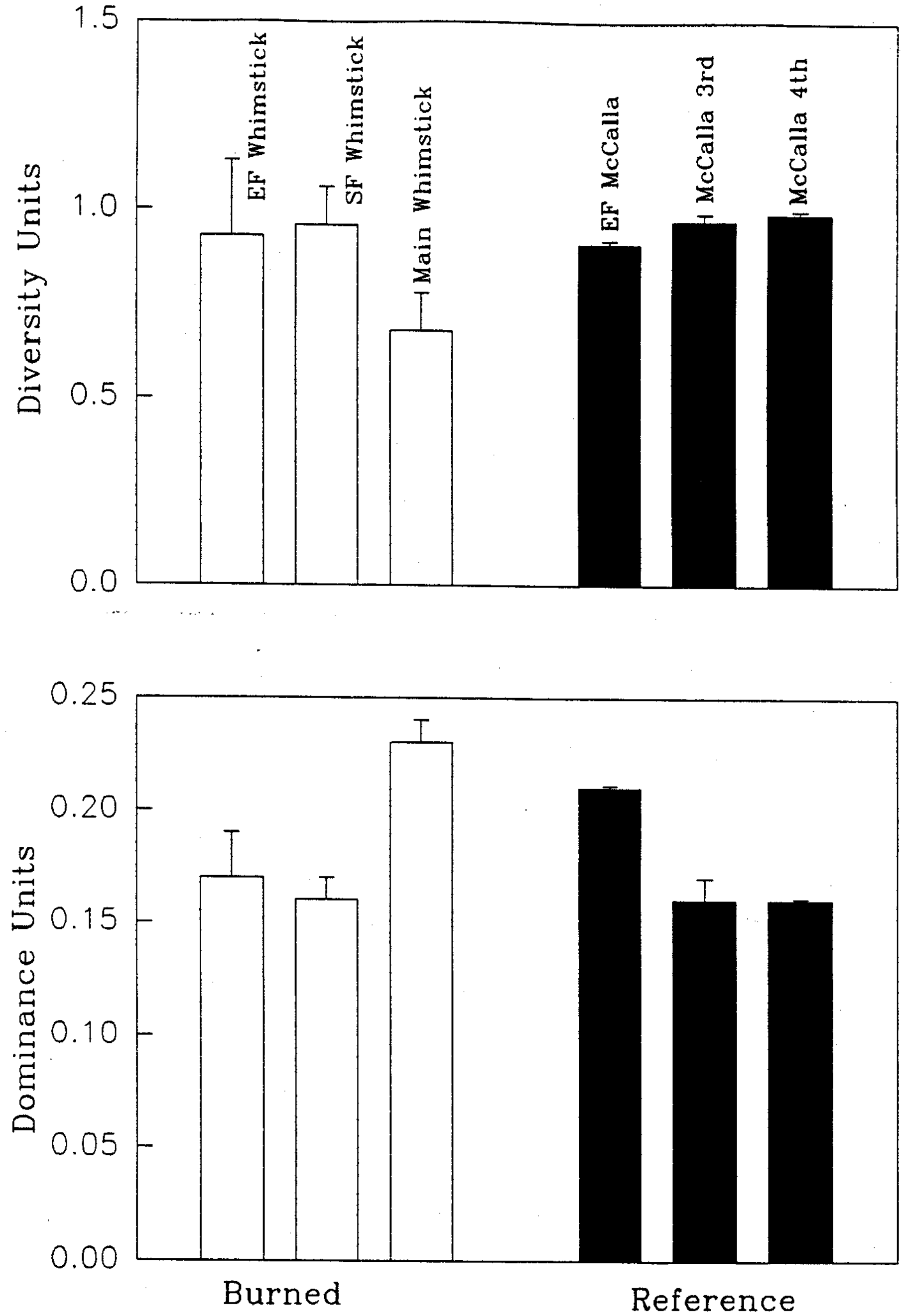


Fig. 14. Mean macroinvertebrate values for Shannon-Weiner Diversity and Simpson's Dominance indices for burned and reference streams within Chamberlin Basin 1991. Vertical bars represent one standard deviation from the mean (n=5).

Goat Creeks. *Drunella doddsi* and *Cinygmula* were abundant only in Cliff Creek (Table 11).

Gatherers and scrapers were abundant in all Sliver Creek Fire sites. *Baetis* was abundant in all streams. *Cinygmula* and *Drunella doddsi* were abundant in Sliver and Packhorse Creeks. These species were replaced in abundance by *Serratella tibialis* and *Epeorus longimanus* in Crooked Creek. Hydracarina was abundant in all streams. The predaceous trichopteran *Rhyacophila* and stonefly *Isoperla* were abundant in Crooked Creek, and *Heterlimnius* was abundant in Packhorse Creek. Shredders were abundant only in Sliver Creek, represented by the plecopteran *Yoroperla brevis* (Table 11).

Chamberlain Basin: Burn versus Reference

Chemical and Physical Measurements: Measurements of channel morphology (H/L, H-L, etc.) clearly indicated channels were more confined in reference streams than burn streams (Table 10). For example, the higher ratio of highflow channel area to baseflow channel area (H/L) in burn streams indicated active, enlarging channels. Mean substrate length was greater in burn streams than in reference streams, and substrate CV's similar.

Burn sites had lower specific conductance than reference sites. Alkalinity and total hardness marginally were lower in burn than reference sites (Table 10). No clear difference in annual temperature range was apparent between burn and reference streams. However, annual temperature range increased with stream order within reference streams.

Periphytic and Benthic Organic Matter: Chlorophyll a and periphyton biomass (AFDM) were greater in burn than in reference sites, except for 2nd order streams (Fig. 12). BOM levels were higher in reference than in burn sites. BOM % charcoal was similar among burn and reference streams.

<u>Macroinvertebrate Community Analysis:</u> Mean macroinvertebrate abundance in burn streams was low in comparison to reference streams except McCalla Creek 3rd order (Fig. 13). Abundance in burn sites ranged from 2503 (EF Whimstick Creek) to 4071 individuals/m^2 (SF Whimstick Creek). Abundance in reference streams ranged from 3,116 (McCalla Creek 3rd) to 14,116 individuals/m^2 (EF McCalla Creek). Mean biomass showed no apparent pattern between burn and reference sites. Here, reference McCalla Creek 3rd order had lower macroinvertebrate biomass than EF McCalla and McCalla 4th order sites. Likewise, EF Whimstick Creek had lower biomass than South Fork or Main Whimstick sites (Fig. 13).

Species richness was less in burn sites than comparable reference sites except McCalla Creek 3rd (Fig. 13). Mean richness varied from 16 to 22 species in the burn streams and from 20 to 28 species in reference streams. Shannon's diversity was similar between 2nd and 3rd order burn and reference sites, and lower in 4th order Whimstick Creek than reference McCalla Creek 4th order (Fig. 14). Diversity was different between burn streams but not between reference streams. Simpson's index was greater in 2nd order EF McCalla Creek than in burn EF Whimstick Creek, while 4th order Whimstick displayed greater dominance values than reference McCalla 4th order.

<u>Macroinvertebrate Taxa Analysis:</u> Differences were apparent in the ten most abundant taxa between burn and reference streams (Table 11). The gatherer-scrapers *Cinygmula*, *Heterlimnius*, *Drunella*, and *Serratella tibialis* occurred in high frequencies in burn streams. The scraper *Baetis intermedius* was abundant in all reference sites. *Cinygmula* and *Heterlimnius* were abundant in EF McCalla and McCalla 4th order Creeks. SF Whimstick Creek was the only burn stream that had an abundant shredder (*Micrasema* at 2.7%). The shredders *Yoroperla brevis* and *Micrasema* were abundant in all reference streams.

Dave Lewis Creek Study: September 1991

Water chemistry varied between streams and sampling times. NO_3, pH, water temperature, and specific conductance were higher in reference Pioneer Creek compared to burn Dave Lewis Creek (Fig. 15). NH_4 ranged from 0.021 mg/l N in Dave Lewis Creek at dusk to 0.011 mg/l N at both sites at dawn. Phosphate levels were similar between sites, although levels were quite low in Dave Lewis Creek at dawn.

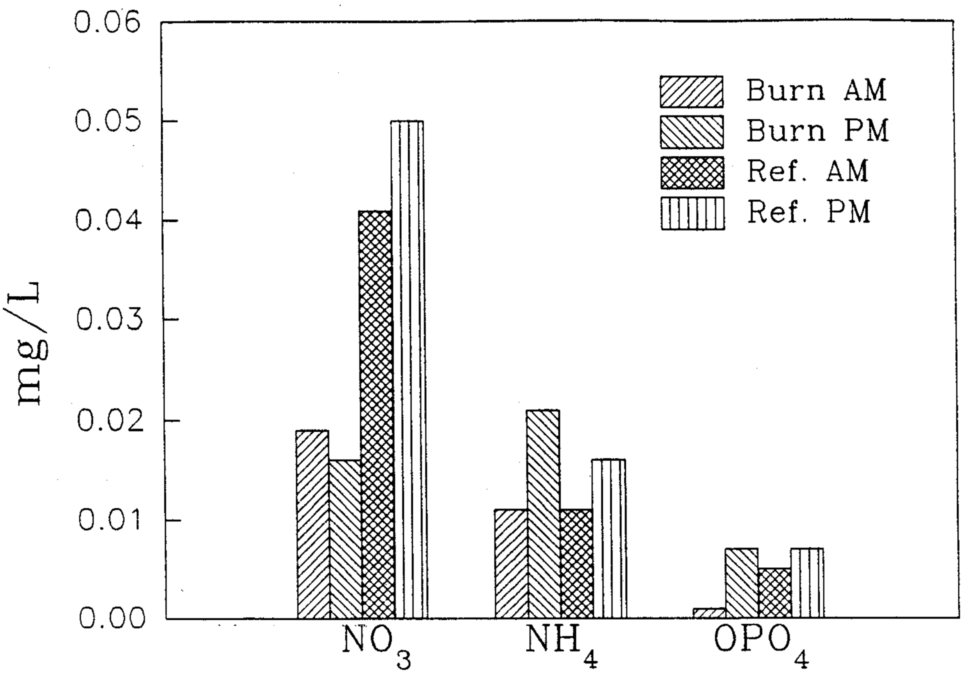
Species richness of drifting macroinvertebrates was not significantly different between streams ($p<0.01$)(Fig. 16). Drift density, at dawn and dusk, was significantly greater in Pioneer Creek than in Dave Lewis Creek ($p<0.01$). Density of dawn drift was significantly greater than dusk drift in Pioneer Creek ($p < 0.01$). No differences in drift density were evident between sampling times in Dave Lewis Creek (Fig. 16). Multiple regression indicated that drift density could be predicted by pH and specific conductance (adjusted $r^2 = 0.95$; see Table 12).

Individual taxa tended to have higher densities in reference Pioneer Creek at dawn than at dusk (Table 13). Seven taxa had significant regression models ($p < 0.05$) and could be predicted by water chemistry variables (Table 12). Densities of all taxa except Collembola were negatively correlated with pH and positively correlated with specific conductance. Collembola could be predicted from NO_3 levels alone.

DISCUSSION/SUMMARY

Cliff Creek Temporal Study: 1988-1991

Cliff Creek, located directly opposite Taylor Ranch, provides an ideal study system on the delayed effects of fire that burned the headwaters of a catchment. As mentioned, the sampling area is located about 3 km downstream of the fire perimeter. Some



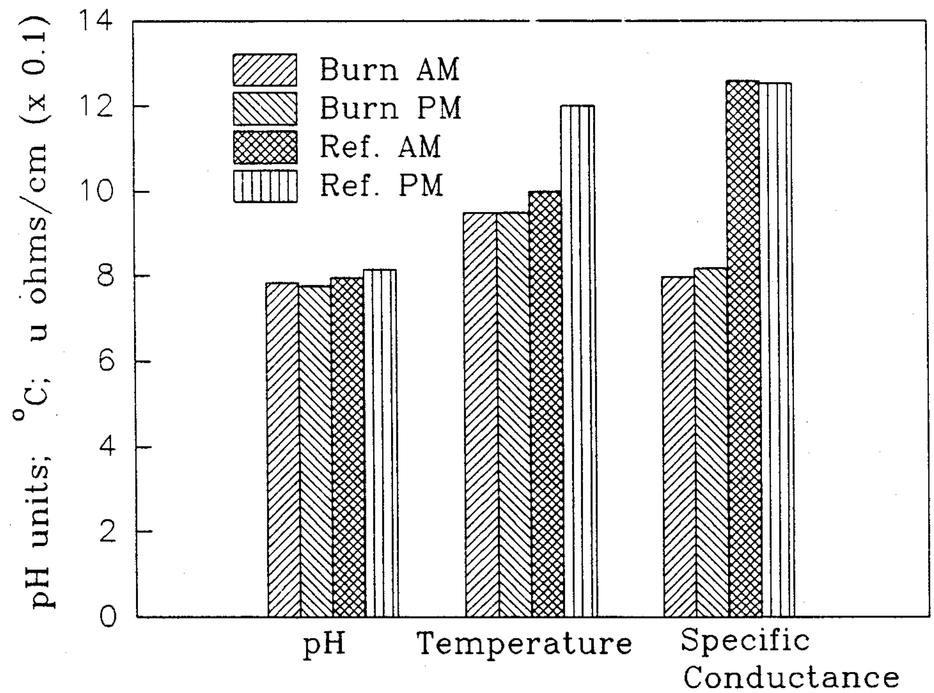


Fig. 15. Water chemistry factors measured at both burn (Dave Lewis) and reference (Pioneer) sites (AM=dawn sample, PM=dusk sample).

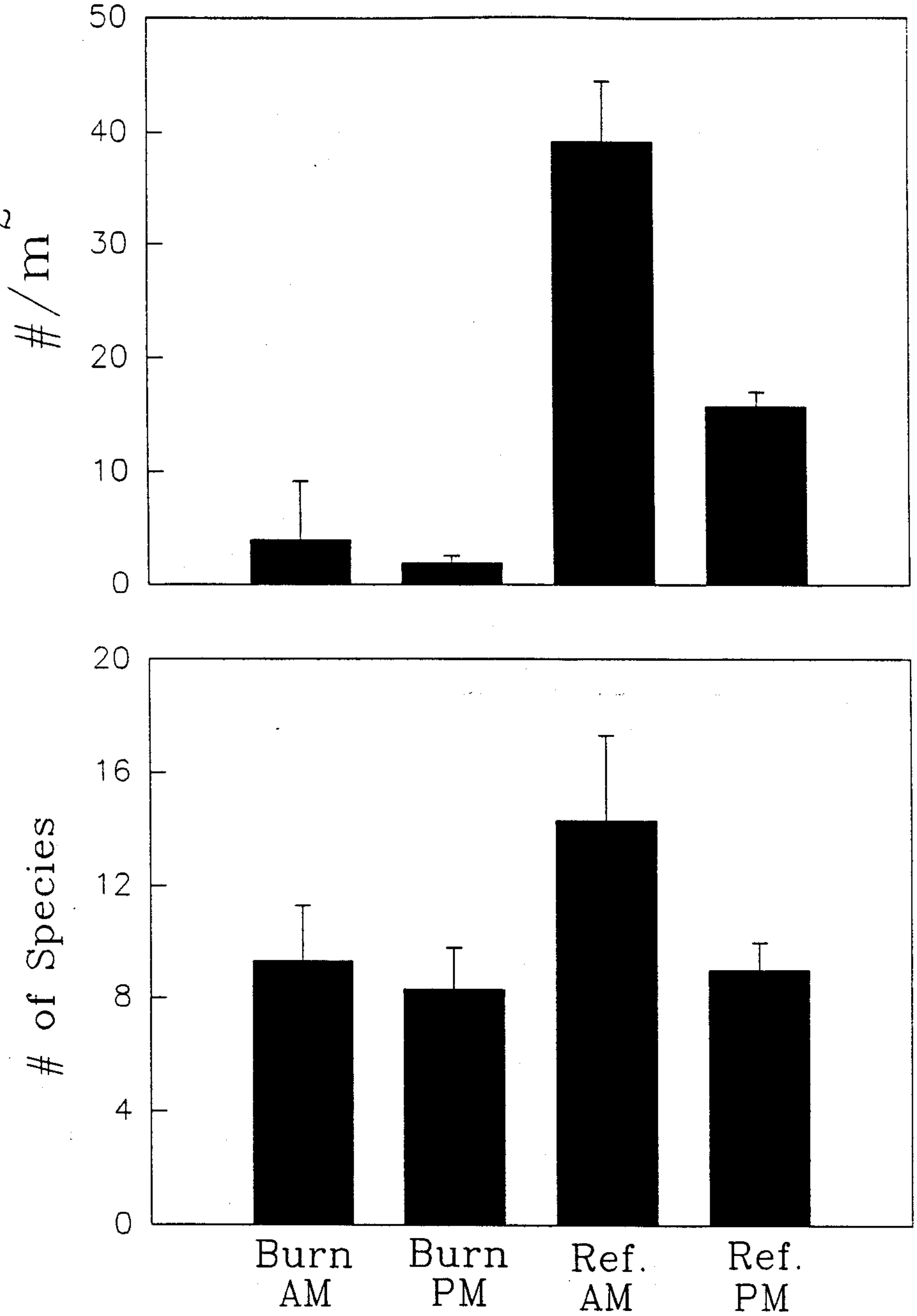


Fig. 16. Mean abundance and species richness of macroinvertebrate drift collected at both burn (Dave Lewis) and reference (Pioneer) sites (AM=dawn sample, PM=dusk sample). Vertical bars represent one standard deviation from the mean (n=3).

Table 12. Standard multiple regression values for drift taxa from both Dave Lewis (burn) and Pioneer (reference) Creeks. All regression models were significant ($p < 0.05$).

TAXA	INDEP VAR	p VALUE	BETA	ADJ. R2
Baetis spp.	pH	0.001	-9.34	0.94
	COND	0.002	26.43	
Chironomidae	pH	0.013	-6.81	0.77
	COND	0.015	24.96	
Collembola	NO3	0.028	1.17	0.98
Ostracoda	pH	0.001	-8.65	0.94
	COND	0.001	24.72	
Simuliidae	pH	0.018	-8.29	0.61
	COND	0.013	32.25	
Zapada spp.	pH	0.001	-7.77	0.87
	COND	0.001	25.82	
TOTAL DENSITY (#/m2)	pH	0.001	-7.27	0.95
	COND	0.001	20.60	

Table 13. Mean density (#/m3) and standard deviation (sd) of the 12 most abundant invertebrate taxa collected in the drift at both burn and reference sites.

TAXA	BURN AM		BURN PM		REF AM		REF PM	
	mean	sd	mean	sd	mean	sd	mean	sd
	----	--	----	--	----	--	----	--
Predator								
Hydracarnia	0.040	0.600			0.370	0.060	0.020	0.040
Suwallia sp.			0.010	0.020	0.050	0.080	0.020	0.040
Gatherer								
Collembola					6.410	1.170	8.890	0.600
Heterlimnius sp.					0.190	0.130	0.060	0.010
Pericoma sp.			0.010	0.001	0.040	0.070		
Polycentropus sp.	0.050	0.060			0.040	0.070	0.020	0.040
Scraper								
Baetis spp.	1.860	2.000	0.150	0.110	12.970	2.800	2.500	0.180
Oligophelbodes spp.	0.210	0.200	0.070	0.080			0.020	0.030
Shredder								
Zapada columbiana	0.250	0.190	0.090	0.050	0.640	0.180	0.150	0.050
Filterer								
Ostracoda	2.310	2.760	0.930	0.420	14.560	3.100	3.300	1.000
Simulium spp.	0.180	0.170			0.260	0.140	0.020	0.040
Miner								
Chironomidae	1.320	1.070	0.520	0.250	2.470	1.100	0.590	0.040

major changes have occurred in Cliff Creek as a result of the fire in the headwater region. Both discharge and annual stream temperature have increased substantially since the fire year. Benthic organic matter has decreased since 1988, but the % charcoal of BOM has increased in this same period. The increase in percent charcoal suggests a pulse of burned organic is moving through the system and thus altering the food quality of particulate organic matter.

Numbers and biomass of benthic macroinvertebrates have remained depressed since the fire, perhaps because of observed changes in food quality. Species richness and diversity (H') decreased, and dominance increased in 1991. Shredder abundance and biomass have remained relatively low since the fire. Filterers peaked in relative biomass during 1989 and 1990, then decreased in 1991. Miner biomass increased dramatically to 42% of the assemblage in 1991. Many of the most abundant taxa, e.g. *Baetis, Cinygmula, Heterlimnius*, Chironomidae, and Oligochaeta, have remained relatively abundant during the four years of study. Exceptions, were *Glossosoma* and *Ephemerella infrequens* being common in 1989, the loss of *Polycentropus* in 1989-1991, and *Serratella tibialis* becoming abundant in 1991. We expect to observe continued delayed effects on the physical and chemical habitat from the fire which should translate into changes within the macroinvertebrate assemblage.

Big Creek Study: 1990-1991

This aspect of our study verified the observed differences in response among streams sampled in 1990 that were impacted by the Golden Fire (Robinson and Minshall 1991). The streams included Cliff, Cougar, Dunce, and Goat Creeks with the Cliff Creek study area located downstream of the fire perimeter. Few physical or chemical changes occurred between 1990 and 1991 in the study streams. Exceptions included decreases in alkalinity and total hardness in Cougar and Goat Creeks. Annual temperatures remained high in all sites except Goat Creek. Benthic organic matter was similar among sites between years, except BOM increased in Dunce Creek in 1991 with a corresponding increase in % charcoal. The increase in BOM and % charcoal suggests enhanced riparian inputs during 1991 in Dunce Creek. Macroinvertebrate abundance and biomass essentially remained unchanged between years, except numbers and diversity decreased and dominance increased in Cliff Creek in 1991. The relative abundance of gatherers decreased, and filterers and miners increased in all sites except Cliff Creek in 1991.

Ground reconnaissance of the lower to middle Cliff Creek and Goat Creek basins was undertaken in July 1991 to better understand the response of these streams to the 1988 Golden Fire. Both streams have shown less impact following fire than we have seen in other streams where catchments were fully burned by a hot (crown) fire. It appears that the moderated effects in Cliff and Goat Creeks were due to a more-restricted burning of the watersheds and, in the case of Cliff Creek, strong geological control of runoff.

As noted elsewhere, Cliff Creek burned only in the upper reaches. The fire did not extend downstream of the base of the cliffs, which are about 2.5 km upstream of where Cliff Creek enters Big Creek (and therefore, a comparable distance above our sampling site). Even the area we examined in the canyon upstream of the base of the cliffs (to just below where the first major tributary enters from the east) was only spottily burned and/or dead needles were still on the trees. The riparian area between the base of the cliffs and our sampling site appeared to be intact and lush, thus buffering the site from any upstream effects from the fire. In addition, the extensive (1.5 km) rocky gorge upstream of the base of the cliffs serves to regulate flows and temper the effects of runoff in and above the gorge on the downstream reach.

Goat Creek was intentionally backburned by firefighters in

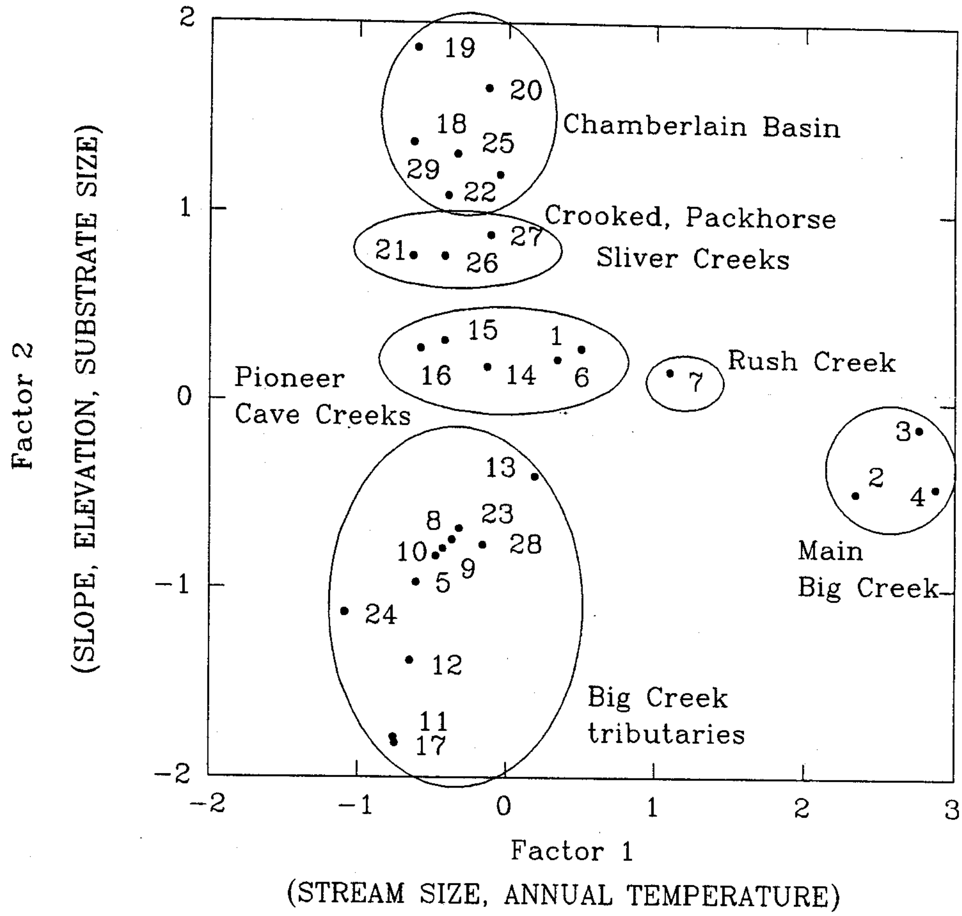


Fig. 17. Principal Components Analysis scatter plot for study streams in Big Creek and Chamberlain Basins based on physical attributes. Clusters were circled for clarity of presentation.

1988. As a result, much of the burned area was restricted to the stream/riparian corridor. The riparian vegetation was burned all the way from the head of the alluvial fan just upstream of Big Creek to at least the first 1st-order tributary entering from the east above the big meadow (a distance of about 2 km above our sampling site). The burned riparian area probably continued all of the way to the top of the catchment but we terminated our inspection at this tributary. The vegetation along the big meadow was burned (mainly in the older stands of birch) but the adjacent fir trees were relatively untouched. Upstream of the big meadow, up to 50% of the trees on the side slopes were burned but many still retain some or many of their needles. On the basis of our observations, we would expect Goat Creek to show the effects of the initial riparian vegetation removal (e.g., increased light and elimination or charring of allochthonous organic matter) and other immediate effects of fire (e.g., increased temperature and chemical substances) but to be spared the intermediate detrimental effects, associated with increased runoff from denuded side slopes, found in more severely burned watersheds (e.g., channel scouring and alteration)(Minshall et al. 1989).

Golden Fire versus Sliver Creek Fire

These data showed subtle differences in recovery dynamics dependent on fire intensity and catchment geomorphology. The Golden Fire burned rather rugged areas within the Big Creek catchment, whereas the Sliver Creek Fire burned more gentle topography. This is evident in differences in channel slopes and characteristics, substrata sizes, and water chemistry between streams influenced by the two fires (Fig. 17). Channels were more open (i.e. less dense riparian conditions) among Sliver Creek Fire streams than among Golden Creek Fire streams. Chlorophyll levels and annual temperatures tended to be greater and BOM lower in Sliver Creek Fire streams than in Golden Creek Fire streams. Associated with these habitat differences are increased numbers, biomass, and species richness in Sliver Creek Fire streams than in Golden Creek Fire streams. Diversity and dominance values were similar among respective fire streams. The general influence of fire on streams was, however, quite similar between the two fires with macroinvertebrate assemblages seemingly depressed in burn streams relative to reference streams.

Chamberlain Basin: Burn versus Reference Streams

The Sliver Creek Fire added important information towards understanding the influence of wildfire on streams (Fig. 17). Two catchments were sampled in 1991, representing the burn and reference condition. As discussed above, stream geomorphology and local climatic conditions were quite different in Chamberlain Basin relative to the Big Creek catchment. Here, chlorophyll levels were greater and BOM lower in burn streams than in reference streams. The % charcoal of BOM was similar among burn and reference streams. Total numbers of macroinvertebrates were lower and biomass similar in burn streams compared to reference streams. Species richness was reduced, but diversity and dominance tended to be similar among burn and reference streams. These data suggest recovery dynamics may be different in different basins as influenced by local geology and climate. Major changes in stream habitat may not occur in low gradient streams as found in Chamberlain Basin, resulting in more rapid recovery following fire of the macroinvertebrate assemblages. Consequently, different temporal trajectories in recovery may occur among basin types following wildfire.

Dave Lewis Creek Fire Study

This study was intended to isolate the immediate effects of wildfire on streams. We attempted to document changes in water chemistry, e.g. increases in nitrogen and phosphorus levels, and increases in macroinvertebrate drift attributed fire. However, the Dave Lewis Creek Fire was a long-term, low intensity, highly dispersed fire thus nullifying expected results. Indeed, the reference Pioneer Creek had greater background levels in most chemical parameters measured, especially nitrate and specific conductance. Further, densities of drifting macroinvertebrates were greater and highly correlated to the greater productive capacity of Pioneer Creek.

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